



Evidence of W $\gamma\gamma$ Production in pp Collisions at $\sqrt{s}=8$ TeV and Limits on Anomalous Quartic Gauge Couplings with the ATLAS Detector

Aad, A.; Abbott, B.; Abdallah, J.; Abdel-Khalek, S.A.; Abdinov, O.; Aben, R.; Abi, B.; Abolins, M.; AbouZeid, O.S.; Abramowicz, H.; Dam, Mogens; Hansen, Jørn Dines; Hansen, Jørgen Beck; Xella, Stefania; Hansen, Peter Henrik; Petersen, Troels Christian; Thomsen, Lotte Ansgaard; Mehlhase, Sascha; Jørgensen, Morten Dam; Pingel, Almut Maria; Løvschall-Jensen, Ask Emil; Alonso Diaz, Alejandro; Monk, James William; Pedersen, Lars Egholm; Wiglesworth, Graig; Galster, Gorm Aske Gram Krohn

Published in:
Physical Review Letters

DOI:
[10.1103/PhysRevLett.115.031802](https://doi.org/10.1103/PhysRevLett.115.031802)

Publication date:
2015

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):

Aad, A., Abbott, B., Abdallah, J., Abdel-Khalek, S. A., Abdinov, O., Aben, R., Abi, B., Abolins, M., AbouZeid, O. S., Abramowicz, H., Dam, M., Hansen, J. D., Hansen, J. B., Xella, S., Hansen, P. H., Petersen, T. C., Thomsen, L. A., Mehlhase, S., Jørgensen, M. D., ... Galster, G. A. G. K. (2015). Evidence of W $\gamma\gamma$ Production in pp Collisions at $\sqrt{s}=8$ TeV and Limits on Anomalous Quartic Gauge Couplings with the ATLAS Detector. *Physical Review Letters*, 115(3), [031802]. <https://doi.org/10.1103/PhysRevLett.115.031802>



Evidence of $W\gamma\gamma$ Production in pp Collisions at $\sqrt{s} = 8$ TeV and Limits on Anomalous Quartic Gauge Couplings with the ATLAS Detector

G. Aad *et al.**

(ATLAS Collaboration)

(Received 11 March 2015; published 16 July 2015)

This Letter reports evidence of triple gauge boson production $pp \rightarrow W(\ell\nu)\gamma\gamma + X$, which is accessible for the first time with the 8 TeV LHC data set. The fiducial cross section for this process is measured in a data sample corresponding to an integrated luminosity of 20.3 fb^{-1} , collected by the ATLAS detector in 2012. Events are selected using the W boson decay to $e\nu$ or $\mu\nu$ as well as requiring two isolated photons. The measured cross section is used to set limits on anomalous quartic gauge couplings in the high diphoton mass region.

DOI: [10.1103/PhysRevLett.115.031802](https://doi.org/10.1103/PhysRevLett.115.031802)

PACS numbers: 12.15.Ji, 13.85.Qk, 14.70.Bh, 14.70.Fm

In the standard model (SM), the self-couplings of the electroweak gauge bosons are specified by the non-Abelian $SU(2) \times U(1)$ structure of the electroweak sector. Since any deviation in the self-couplings from this expectation indicates the presence of new physics phenomena at unprobed energy scales, the measurement of the production of multiple electroweak gauge bosons represents an important test of the SM. This Letter presents a measurement of the triboson production cross section, discussed in Ref. [1], where the W boson decays into $e\nu$ or $\mu\nu$ [$W(\ell\nu)\gamma\gamma$], and its sensitivity to anomalous quartic gauge couplings (AQGCs) $WW\gamma\gamma$. Such final states mainly come from events where the W boson is produced in the hard interaction between the two partons, and the photons either originate from initial or final state radiation processes, or from triple or quartic gauge vertices together with the W boson. The inclusive and exclusive cross sections are both measured. The inclusive case has no restriction on the $W\gamma\gamma$ recoil system, whereas the exclusive case includes a veto on events containing one or more jets. Limits on AQGC parameters are set in the exclusive phase space with a diphoton mass larger than 300 GeV. Total and differential cross sections for the diboson production processes WW , WZ , ZZ , $W\gamma$, and $Z\gamma$ have been reported previously by the ATLAS [2–5], CMS [6–8], D0 [9–11], and CDF [12–14] Collaborations, including limits on anomalous triple gauge boson couplings. Limits have been set on AQGCs by ATLAS [15], CMS [16,17], the LEP experiments [18–21], and D0 [22].

ATLAS [23] is a multipurpose detector composed of an inner tracking detector (ID) surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field,

electromagnetic (EM) and hadronic calorimeters, and a muon spectrometer (MS) immersed in the magnetic field produced by a system of superconducting toroids. Events in this analysis are selected with triggers requiring the presence of one muon with a transverse momentum (p_T) of more than 18 GeV and two electromagnetic objects with a transverse energy (E_T) of more than 10 GeV each, with an efficiency of about 80% [24], or three $E_T > 15$ GeV electromagnetic objects with an efficiency of more than 95% [25,26]. After applying data quality requirements, the data set corresponds to a total integrated luminosity of $20.3 \pm 0.6 \text{ fb}^{-1}$ [27].

The main backgrounds to the $W(\ell\nu)\gamma\gamma$ process originate from processes with jets identified as photons or leptons, referred to as fakes hereafter. Data-driven techniques are used to estimate fakes, whereas Monte Carlo (MC) simulation is used to estimate background sources with prompt leptons and photons and for the signal. The SHERPA 1.4.1 generator [28–31] is used to model the signal with up to three partons in the final state. SHERPA was also used to simulate the $Z\gamma$, $Z\gamma\gamma$, WZ , and $W(\tau\nu)\gamma\gamma$ backgrounds. For the $Z\gamma$ background, the agreement between data and the MC prediction was assessed in Z -enriched control regions. The $t\bar{t}$, single top, and WW processes are modeled by MC@NLO 4.02 [32,33], interfaced to HERWIG 6.520 [34] for parton showering and fragmentation processes and to JIMMY 4.30 [35] for underlying event simulation. The POWHEG [36] generator is used to simulate ZZ production, interfaced to PYTHIA 8.163 [37] for parton showering and fragmentation. The CT10 parton distribution function (PDF) set [38] is used for all SHERPA, MC@NLO, and POWHEG samples. The standard ATLAS detector simulation [39] based on GEANT4 [40] is used. It includes multiple proton-proton interactions per bunch crossing (pileup) as observed in data.

The $W(\ell\nu)\gamma\gamma$ candidate events contain an isolated lepton and missing transverse momentum (E_T^{miss}) from the undetected neutrino of the leptonic W decay, and two isolated

*Full author list given at the end of the article.

Published by the American Physical Society under the terms of the *Creative Commons Attribution 3.0 License*. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

photons (including also photons that have converted in electron-positron pairs within the ID volume). Muon candidates are identified, within pseudorapidity [26] $|\eta| < 2.4$, by associating complete tracks or track segments in the MS with tracks in the ID [41]. Electron candidates are reconstructed within $|\eta| < 2.47$ as electromagnetic clusters associated to a track [42], whereas photons are reconstructed as electromagnetic clusters with $|\eta| < 2.37$ [43]. The calorimeter transition regions at $1.37 < |\eta| < 1.52$ are excluded for electrons and photons. Identification criteria based on shower shapes in the EM calorimeter for photons, and additionally on tracking information for electrons, referred to as “tight” in Refs. [42,44], are used. The E_T^{miss} uses the energy deposits in the calorimeters within $|\eta| < 4.9$ and the muons identified in the MS, as described in Ref. [45]. Reconstructed muons, electrons, and photons are required to have $p_T^{\mu,e,\gamma} > 20$ GeV and to be isolated. Photons are considered isolated if the sum of calorimeter transverse energy deposits in a cone of size $\Delta R = 0.4$ around the candidate is smaller than 4 GeV. The isolation is corrected for photon energy leakage. The muon isolation is based on the sum of the transverse momenta of ID tracks in a cone of size $\Delta R = 0.2$ which must be below $0.15 \times p_T^\mu$. For electrons, the calorimeter transverse energy deposits and the sum of the transverse momenta of tracks in a cone of size $\Delta R = 0.2$ must be below $0.2 \times p_T^e$ and $0.15 \times p_T^e$, respectively. The lepton must also be compatible with originating from the primary vertex of the interaction, which is taken to be the vertex with the largest Σp_T^2 of associated tracks. E_T^{miss} is required to exceed 25 GeV. The transverse mass of the W boson [46] is required to be greater than 40 GeV. The two photons must be outside of their mutual isolation cones by requiring $\Delta R(\gamma, \gamma) > 0.4$. To suppress the contribution from final-state radiation, the lepton and photons are required to have $\Delta R(\ell, \gamma) > 0.7$. Events containing a second reconstructed lepton are rejected to reduce background from Drell-Yan events. In the electron channel, additional requirements are used to suppress events in which one electron is misidentified as a photon (mainly originated from the $Z\gamma$ process): the transverse momentum of the $e\gamma\gamma$ system is required to

be greater than 30 GeV, and the invariant mass of the electron and the leading, subleading or both photons is required to be outside a 13, 8 or 15 GeV wide window around the Z boson mass, respectively. Exclusive events are defined with a veto on additional jets compared to the inclusive selection. Jets are reconstructed from clustered energy deposits in the calorimeter using the anti- k_t algorithm [47] with radius parameter $R = 0.4$ and are required to have $p_T > 30$ GeV and $|\eta| < 4.4$. Jets at $\Delta R < 0.3$ from the selected lepton and photons are rejected. In order to reduce pileup effects, for jets with $p_T < 50$ GeV and $|\eta| < 2.4$, more than 50% of the summed scalar p_T of tracks within $\Delta R = 0.4$ of the jet axis must be from tracks associated to the primary vertex.

Table I shows the expected background as well as the observation. The background expectation alone is not sufficient to describe the data indicating the presence of signal events. The fake-photon background from $W\gamma j + Wjj$ is estimated by performing a two-dimensional template fit to the isolation energy distributions of the leading and subleading photons, as described in Ref. [48]. Three background templates are obtained from data by reversing some of the photon identification requirements based on shower shape; the signal templates are taken from MC simulation. Contributions from events where a jet satisfies the electron identification criteria, or the muon originates from heavy-flavor decays, i.e. from $\gamma\gamma + \text{jets}$ processes, are estimated by using a two-dimensional sideband method constructed from the lepton isolation and E_T^{miss} variables, as described in Ref. [5]. The distribution of the diphoton invariant mass in the two channels is shown in Fig. 1. Alternative methods have been used to cross-check the estimate of the backgrounds coming from fakes, all of them provide consistent results. In the estimation of the fake-photon background, systematic uncertainties arise from the limited number of events in the control regions, the functional form used to describe the background isolation energy distribution, the definition of the control region, the modeling of the signal in the MC samples and the corresponding statistical uncertainty. In the estimate of the fake-lepton background, systematic uncertainties related to

TABLE I. The background composition in each channel is shown for the inclusive (left) and exclusive (right) cases. The $W\gamma j + Wjj$ and $\gamma\gamma + \text{jets}$ backgrounds are estimated using data-driven techniques, whereas the others are extracted from MC simulation. The number of candidate events in data passing the full selection is also shown.

| | Electron channel | Muon channel | Electron channel | Muon channel |
|------------------------------|--|--|---|--|
| | $N_{\text{jet}} \geq 0$ | | $N_{\text{jet}} = 0$ | |
| $W\gamma j + Wjj$ | $15.3 \pm 4.8(\text{stat}) \pm 5.3(\text{syst})$ | $30.5 \pm 7.7(\text{stat}) \pm 6.8(\text{syst})$ | $5.8 \pm 2.1(\text{stat}) \pm 2.0(\text{syst})$ | $14.4 \pm 4.9(\text{stat}) \pm 4.9(\text{syst})$ |
| $\gamma\gamma + \text{jets}$ | $1.5 \pm 0.6(\text{stat}) \pm 1.0(\text{syst})$ | $11.0 \pm 4.0(\text{stat}) \pm 4.9(\text{syst})$ | $0.2 \pm 0.2(\text{stat}) \pm 0.2(\text{syst})$ | $6.1 \pm 3.5(\text{stat}) \pm 3.1(\text{syst})$ |
| $Z\gamma$ | $11.2 \pm 1.1(\text{stat})$ | $3.9 \pm 0.2(\text{stat})$ | $2.4 \pm 0.5(\text{stat})$ | $2.8 \pm 0.2(\text{stat})$ |
| Other backgrounds | $2.2 \pm 0.6(\text{stat})$ | $6.7 \pm 2.0(\text{stat})$ | $0.3 \pm 0.1(\text{stat})$ | $1.1 \pm 0.3(\text{stat})$ |
| Total background | $30.2 \pm 5.0(\text{stat}) \pm 5.4(\text{syst})$ | $52.1 \pm 8.9(\text{stat}) \pm 8.4(\text{syst})$ | $8.7 \pm 2.2(\text{stat}) \pm 2.0(\text{syst})$ | $24.4 \pm 6.0(\text{stat}) \pm 5.8(\text{syst})$ |
| Data | 47 | 110 | 15 | 53 |

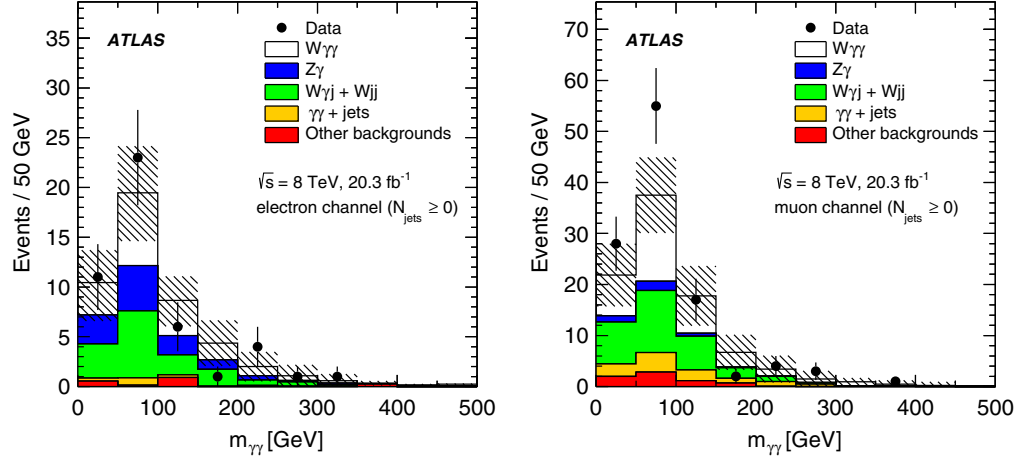


FIG. 1 (color online). Diphoton invariant mass distribution in the electron (left) and muon (right) channels. The expected signal based on the SHERPA prediction is shown. The hashed areas show the total systematic and statistical uncertainty on the background estimate.

the control region definitions and the residual correlation of the discriminating variables are considered.

The fiducial cross sections $\sigma_{W\gamma\gamma}^{\text{fid}}$ are obtained from a maximum-likelihood fit, similarly to Ref. [5], for the electron channel, the muon channel, and the combination of the two assuming lepton universality to determine the $W(\ell\nu)\gamma\gamma$ cross section for a single lepton flavor. They are measured in a phase space, defined in Table II, close to that of the experimentally selected region. Here p_T^ν is the transverse momentum of the neutrino and ϵ_h^p is the fractional energy carried by the closest particle-level jet in a cone of $\Delta R = 0.4$ around each photon direction.

The efficiency of the signal selection and the small acceptance correction due to the extrapolation over the calorimeter transition region and to $|\eta| = 2.5$ for the leptons are taken into account in the procedure. The acceptance correction factors are 0.83 and 0.90 in the electron and muon channel, respectively. The combined efficiency and acceptance correction amounts to $(19.6 \pm 0.5)\%$ and $(40.4 \pm 0.7)\%$ in the electron and muon channels in the inclusive case, and to $(15.1 \pm 0.7)\%$ and $(39.7 \pm 1.0)\%$ in the exclusive case. The given uncertainties are statistical only. Corrections are applied to account for small differences between data and MC simulation in lepton, photon, and jet efficiencies, momentum scale and resolution, additional pp interactions, and beam-spot position.

TABLE II. Definition of the fiducial region for which the cross section is evaluated.

| Definition of the fiducial region |
|---|
| $p_T^\ell > 20$ GeV, $p_T^\nu > 25$ GeV, $ \eta_\ell < 2.5$ |
| $m_T > 40$ GeV |
| $E_T^\gamma > 20$ GeV, $ \eta^\gamma < 2.37$, iso. fraction $\epsilon_h^p < 0.5$ |
| $\Delta R(\ell, \gamma) > 0.7$, $\Delta R(\gamma, \gamma) > 0.4$, $\Delta R(\ell/\gamma, \text{jet}) > 0.3$ |
| Exclusive: no anti- k_t jets with $p_T^{\text{jet}} > 30$ GeV, $ \eta^{\text{jet}} < 4.4$ |

Systematic uncertainties on the cross section are accounted for by introducing nuisance parameters in the likelihood which modify the signal and background expected yields. Correlations between systematic uncertainties in the two channels are accounted for in the combined fit. When combining the two channels, the dominant systematic uncertainties in the inclusive and exclusive cross-section measurements are 14% and 23% from the data-driven background estimates, 5% to 7% from the jet energy scale, and 3% from the luminosity. Other systematic uncertainties considered stem from the electromagnetic and muonic energy scale and resolution, the object reconstruction, the pileup description, and the trigger efficiency. These are found to have a minor impact, below 3%. Theoretical uncertainties on the signal modeling, affecting only the acceptance extrapolation, are negligible. The measured cross sections are shown in Table III. The significance after combining the two channels is larger than 3σ in the inclusive case. The measurements in the electron and muon channels are compatible within 1σ .

The SM prediction for the $W(\ell\nu)\gamma\gamma$ cross section is calculated with the parton-level Monte Carlo program MCFM [49] at next-to-leading order (NLO). The

TABLE III. Measurement of the $pp \rightarrow \ell\nu\gamma\gamma + X$ inclusive and exclusive fiducial cross sections.

| | σ^{fid} (fb) | σ^{MCFM} (fb) |
|---------------------------------------|--|-----------------------------|
| Inclusive ($N_{\text{jet}} \geq 0$) | | |
| $\mu\nu\gamma\gamma$ | $7.1^{+1.3}_{-1.2}(\text{stat}) \pm 1.5(\text{syst}) \pm 0.2(\text{lumi})$ | 2.90 ± 0.16 |
| $e\nu\gamma\gamma$ | $4.3^{+1.8}_{-1.6}(\text{stat})^{+1.9}_{-1.8}(\text{syst}) \pm 0.2(\text{lumi})$ | |
| $\ell\nu\gamma\gamma$ | $6.1^{+1.1}_{-1.0}(\text{stat}) \pm 1.2(\text{syst}) \pm 0.2(\text{lumi})$ | |
| Exclusive ($N_{\text{jet}} = 0$) | | |
| $\mu\nu\gamma\gamma$ | $3.5 \pm 0.9(\text{stat})^{+1.1}_{-1.0}(\text{syst}) \pm 0.1(\text{lumi})$ | 1.88 ± 0.20 |
| $e\nu\gamma\gamma$ | $1.9^{+1.4}_{-1.1}(\text{stat})^{+1.1}_{-1.2}(\text{syst}) \pm 0.1(\text{lumi})$ | |
| $\ell\nu\gamma\gamma$ | $2.9^{+0.8}_{-0.7}(\text{stat})^{+1.0}_{-0.9}(\text{syst}) \pm 0.1(\text{lumi})$ | |

calculations are performed using the MCFM default electroweak parameters [50] and the CT10 PDF set. The renormalization and factorization scales are set to the invariant mass of the $\ell\nu\gamma\gamma$ system. The fragmentation of quarks and gluons to photons is included using the fragmentation function GDRG_LO [51]. The kinematic requirements at parton level match the fiducial acceptance of Table II.

In addition to the inclusive prediction, an exclusive cross section is obtained by vetoing events with an additional jet emission. To account for the difference between jets defined at parton and particle levels, a correction factor of about 0.87 in the exclusive case is computed and applied to the prediction as documented in Ref. [5]. Uncertainties on the two predictions include the effect of varying independently the renormalization and factorization scales by factors of 0.5 and 2.0, evaluating the CT10 PDF error sets scaled to the 68% confidence level (C.L.), the uncertainties on quark or gluon fragmentation to a photon, and the parton to particle correction factors. The predictions for $W(\ell\nu)\gamma\gamma$ production are compared to the measured cross sections in Table III. The measured cross section is higher by 1.9σ in the inclusive case, while better agreement is seen in the exclusive case, similar to the measurement of $W\gamma$ and $Z\gamma$ in Ref. [5]. In the case of $Z\gamma$ and $W\gamma$, higher order corrections were calculated to be smaller for the exclusive compared to the inclusive case [52]. As the process $W\gamma\gamma$ has similar properties, the exclusive measurement is expected to be in better agreement with the theoretical prediction than the inclusive one. Therefore, in the following, the exclusive measurement will be used for the AQGC limits setting, as done in Ref. [5].

The AQGCs are introduced as dimension-8 operators following the formalism defined in the Appendix of Ref. [53]. While many operators give rise to anomalous couplings of the form $WW\gamma\gamma$, this study is restricted to f_{T0}/Λ^4 , f_{M2}/Λ^4 , and f_{M3}/Λ^4 , where Λ represents the scale at which new physics appears, and f the coupling of the respective operator. The $W\gamma\gamma$ final state is expected to be particularly sensitive to the $T0$ operator, whereas the other two operators can be related to the parameters of the dimension-6 operators used at LEP [18–21] and by CMS [16] via the transformations described in Ref. [54]. To preserve unitarity up to high energy scales, a form factor is introduced which depends on the energy, the form factor scale Λ_{FF} and an exponent n , following the formalism described in Refs. [55,56]. The scale Λ_{FF} is independent of the new physics scale Λ [57]. The largest form factor scale ensuring unitarity for this process at $\sqrt{s} = 8$ TeV, calculated using the VBFNLO generator [58–61], is given by $n = 2$ and $\Lambda_{\text{FF}} = 600$ GeV for f_{T0}/Λ^4 , and $\Lambda_{\text{FF}} = 500$ GeV for f_{M2}/Λ^4 and f_{M3}/Λ^4 .

Deviations from the SM prediction for the AQGC parameters, which are predicted to be zero, lead to an

TABLE IV. Observed and expected 95% C.L. limits obtained for the f_{T0}/Λ^4 , f_{M2}/Λ^4 and f_{M3}/Λ^4 AQGC parameters for the combination of the two channels. The values of $n = 0, 1, 2$ are the exponential choices of the form factor, Λ_{FF} is fixed to 600 GeV for f_{T0}/Λ^4 and to 500 GeV for the other parameters. The $n = 0$ choice produces the limits without the form factor applied.

| | | Observed (TeV ⁻⁴) | Expected (TeV ⁻⁴) |
|---------|--------------------|-------------------------------|-------------------------------|
| $n = 0$ | f_{T0}/Λ^4 | $[-0.9, 0.9] \times 10^2$ | $[-1.2, 1.2] \times 10^2$ |
| | f_{M2}/Λ^4 | $[-0.8, 0.8] \times 10^4$ | $[-1.1, 1.1] \times 10^4$ |
| | f_{M3}/Λ^4 | $[-1.5, 1.4] \times 10^4$ | $[-1.9, 1.8] \times 10^4$ |
| $n = 1$ | f_{T0}/Λ^4 | $[-7.6, 7.3] \times 10^2$ | $[-9.6, 9.5] \times 10^2$ |
| | f_{M2}/Λ^4 | $[-4.4, 4.6] \times 10^4$ | $[-5.7, 5.9] \times 10^4$ |
| | f_{M3}/Λ^4 | $[-8.9, 8.0] \times 10^4$ | $[-11.0, 10.0] \times 10^4$ |
| $n = 2$ | f_{T0}/Λ^4 | $[-2.7, 2.6] \times 10^3$ | $[-3.5, 3.4] \times 10^3$ |
| | f_{M2}/Λ^4 | $[-1.3, 1.3] \times 10^5$ | $[-1.6, 1.7] \times 10^5$ |
| | f_{M3}/Λ^4 | $[-2.9, 2.5] \times 10^5$ | $[-3.7, 3.3] \times 10^5$ |

excess of events with high diphoton invariant mass. The phase space to study AQGCs was optimized using the expected significance calculated on simulated events. The optimal phase space was found to be the exclusive selection with the additional requirement of $m_{\gamma\gamma} > 300$ GeV. The SM backgrounds in this region are determined from a fit to the observed $m_{\gamma\gamma}$ distribution. The expected SM background is $0.01 \pm 0.03(\text{stat}) \pm 0.20(\text{syst})$ [$0.02 \pm 0.05(\text{stat}) \pm 0.46(\text{syst})$] events in the electron (muon) channel, where uncertainties include systematic effects due to the extrapolation procedure, depending on the modeling of the spectrum and on the initial background estimate used in the extrapolation. No events are observed in the high-mass region.

The cross-section prediction as a quadratic function of the AQGC parameters is obtained by using VBFNLO [58–61]. For SM couplings, VBFNLO agrees with MCFM. The limits on the AQGC parameters are extracted with a frequentist profile likelihood test [62], using the methodology of Ref. [5]. The expected and observed limits at 95% C.L. on the AQGC parameters are shown in Table IV for different values of n . The limits on f_{M2}/Λ^4 and f_{M3}/Λ^4 improve on the previous results from LEP [18–21] and D0 [22], but are less stringent than those from CMS [16,17]. The limit on f_{T0}/Λ^4 is tighter than the previous limit published by CMS [17,63]. This can be explained by the fact that f_{T0}/Λ^4 is especially sensitive to transversely polarized W bosons, which are favored in the present study [53].

In summary, evidence for the $W(\ell\nu)\gamma\gamma$ process is reported for the first time. The significance of the inclusive production cross section is larger than 3σ . The measured cross sections are in agreement within uncertainties with NLO SM predictions calculated with MCFM. Limits are set at 95% C.L. on the AQGC parameters, in particular improving the limit on f_{T0}/Λ^4 .

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC, and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST, and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR, and VSC CR, Czech Republic; DNRF, DNSRC, and Lundbeck Foundation, Denmark; EPLANET, ERC, and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG, and AvH Foundation, Germany; GSRT and NSRF, Greece; RGC, Hong Kong SAR, China; ISF, MINERVA, GIF, I-CORE, and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MSTB, Serbia; MSSR, Slovakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF, and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society, and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK), and BNL (USA) and in the Tier-2 facilities worldwide.

[1] U. Baur, T. Han, N. Kauer, R. Sobey, and D. Zeppenfeld, *Phys. Rev. D* **56**, 140 (1997).
 [2] ATLAS Collaboration, *Phys. Rev. D* **87**, 112001 (2013).
 [3] ATLAS Collaboration, *Eur. Phys. J. C* **72**, 2173 (2012).
 [4] ATLAS Collaboration, *J. High Energy Phys.* 03 (2013) 128.
 [5] ATLAS Collaboration, *Phys. Rev. D* **87**, 112003 (2013).
 [6] CMS Collaboration, *J. High Energy Phys.* 01 (2013) 063.
 [7] CMS Collaboration, *Phys. Lett. B* **740**, 250 (2015).
 [8] CMS Collaboration, *Phys. Rev. D* **89**, 092005 (2014).
 [9] V. Abazov *et al.* (D0 Collaboration), *Phys. Rev. D* **85**, 112005 (2012).
 [10] V. Abazov *et al.* (D0 Collaboration), *Phys. Rev. Lett.* **107**, 241803 (2011).
 [11] V. Abazov *et al.* (D0 Collaboration), *Phys. Lett. B* **718**, 451 (2012).
 [12] T. Aaltonen *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **104**, 201801 (2010).
 [13] T. Aaltonen *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **108**, 101801 (2012).

[14] T. Aaltonen *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **107**, 051802 (2011).
 [15] ATLAS Collaboration, *Phys. Rev. Lett.* **113**, 141803 (2014).
 [16] CMS Collaboration, *J. High Energy Phys.* 07 (2013) 116.
 [17] CMS Collaboration, *Phys. Rev. D* **90**, 032008 (2014).
 [18] A. Heisler *et al.* (ALEPH Collaboration), *Phys. Lett. B* **602**, 31 (2004).
 [19] J. Abdallah *et al.* (DELPHI Collaboration), *Eur. Phys. J. C* **31**, 139 (2003).
 [20] P. Achard *et al.* (L3 Collaboration), *Phys. Lett. B* **527**, 29 (2002).
 [21] G. Abbiendi *et al.* (OPAL Collaboration), *Phys. Lett. B* **471**, 293 (1999).
 [22] V. Abazov *et al.* (D0 Collaboration), *Phys. Rev. D* **88**, 012005 (2013).
 [23] ATLAS Collaboration, *J. Instrum.* **3**, S08003 (2008).
 [24] ATLAS Collaboration, *Eur. Phys. J. C* **75**, 120 (2015).
 [25] ATLAS Collaboration, Report. No. ATLAS-CONF-2012-048, <https://cds.cern.ch/record/1450089>.
 [26] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis along the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse (x, y) plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$. The distance ΔR in the (η, ϕ) space is defined as $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.
 [27] ATLAS Collaboration, *Eur. Phys. J. C* **73**, 2518 (2013).
 [28] T. Gleisberg, S. Höche, F. Krauss, M. Schönherr, S. Schumann, F. Siegert, and J. Winter, *J. High Energy Phys.* 02 (2009) 007.
 [29] S. Höche, F. Krauss, S. Schumann, and F. Siegert, *J. High Energy Phys.* 05 (2009) 053.
 [30] T. Gleisberg and S. Höche, *J. High Energy Phys.* 12 (2008) 039.
 [31] S. Schumann and F. Krauss, *J. High Energy Phys.* 03 (2008) 038.
 [32] S. Frixione and B. R. Webber, *J. High Energy Phys.* 06 (2002) 029.
 [33] S. Frixione, F. Stoeckli, P. Torrielli, and B. R. Webber, *J. High Energy Phys.* 01 (2011) 053.
 [34] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber, *J. High Energy Phys.* 01 (2001) 010.
 [35] J. M. Butterworth, J. R. Forshaw, and M. H. Seymour, *Z. Phys. C* **72**, 637 (1996).
 [36] T. Melia, P. Nason, R. Röntsch, and G. Zanderighi, *J. High Energy Phys.* 11 (2011) 078.
 [37] T. Sjöstrand, S. Mrenna, and P. Z. Skands, *Comput. Phys. Commun.* **178**, 852 (2008).
 [38] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin, and C.-P. Yuan, *Phys. Rev. D* **82**, 074024 (2010).
 [39] ATLAS Collaboration, *Eur. Phys. J. C* **70**, 823 (2010).
 [40] S. Agostinelli *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **506**, 250 (2003).
 [41] ATLAS Collaboration, *Eur. Phys. J. C* **74**, 3130 (2014).
 [42] ATLAS Collaboration, *Eur. Phys. J. C* **74**, 2941 (2014).

- [43] ATLAS Collaboration, *Eur. Phys. J. C* **74**, 3071 (2014).
 [44] ATLAS Collaboration, Report No. ATLAS-CONF-2012-123, <http://cdsweb.cern.ch/record/1473426>.
 [45] ATLAS Collaboration, Report No. ATLAS-CONF-2013-082, <http://cds.cern.ch/record/1570993>.
 [46] The transverse mass of the W is defined, using the lepton (ℓ) and neutrino (ν) p_T and ϕ , as $m_T = \sqrt{2p_T^\ell p_T^\nu [1 - \cos(\phi_\ell - \phi_\nu)]}$.
 [47] M. Cacciari, G. P. Salam, and G. Soyez, *J. High Energy Phys.* **04** (2008) 063.
 [48] ATLAS Collaboration, *Phys. Rev. D* **85**, 012003 (2012).
 [49] J. M. Campbell, R. K. Ellis, and C. Williams (private communication).
 [50] J. M. Campbell, R. K. Ellis, and C. Williams, MCFM v6.8 Manual, <http://mcfm.fnal.gov/mcfm.pdf>.
 [51] A. Gehrmann-De Ridder and E. W. N. Glover, *Nucl. Phys. B* **517**, 269 (1998).
 [52] M. Grazzini, S. Kallweit, and D. Rathlev, [arXiv:1504.01330](https://arxiv.org/abs/1504.01330).
 [53] O. J. P. Eboli, M. C. Gonzalez-Garcia, and J. K. Mizukoshi, *Phys. Rev. D* **74**, 073005 (2006).
 [54] C. Degrande *et al.*, [arXiv:1309.7890](https://arxiv.org/abs/1309.7890).
 [55] U. Baur and D. Zeppenfeld, *Phys. Lett. B* **201**, 383 (1988).
 [56] H. Aihara *et al.*, [arXiv:hep-ph/9503425](https://arxiv.org/abs/hep-ph/9503425).
 [57] C. Degrande, N. Greiner, W. Kilian, O. Mattelaer, H. Mebane, T. Stelzer, S. Willenbrock, and C. Zhang, *Ann. Phys.* **335**, 21 (2013).
 [58] J. Baglio *et al.*, [arXiv:1107.4038](https://arxiv.org/abs/1107.4038).
 [59] J. Baglio *et al.*, [arXiv:1404.3940](https://arxiv.org/abs/1404.3940).
 [60] K. Arnold *et al.*, *Comput. Phys. Commun.* **180**, 1661 (2009).
 [61] G. Bozzi, F. Campanario, M. Rauch, and D. Zeppenfeld, *Phys. Rev. D* **83**, 114035 (2011).
 [62] A. L. Read, *J. Phys. G* **28**, 2693 (2002).
 [63] VBFNLO uses a slightly different definition of the field strength tensors than Ref. [53]. Therefore, the couplings f need to be scaled for comparison. In the case of f_{T0} , the scale factor is g^{-4} , where g is the $SU(2)$ gauge coupling [58].

G. Aad,⁸⁵ B. Abbott,¹¹³ J. Abdallah,¹⁵² S. Abdel Khalek,¹¹⁷ O. Abdinov,¹¹ R. Aben,¹⁰⁷ B. Abi,¹¹⁴ M. Abolins,⁹⁰ O. S. AbouZeid,¹⁵⁹ H. Abramowicz,¹⁵⁴ H. Abreu,¹⁵³ R. Abreu,³⁰ Y. Abulaiti,^{147a,147b} B. S. Acharya,^{165a,165b,b} L. Adamczyk,^{38a} D. L. Adams,²⁵ J. Adelman,¹⁰⁸ S. Adomeit,¹⁰⁰ T. Adye,¹³¹ T. Agatonovic-Jovin,¹³ J. A. Aguilar-Saavedra,^{126a,126f} M. Agustoni,¹⁷ S. P. Ahlen,²² F. Ahmadov,^{65,c} G. Aielli,^{134a,134b} H. Akerstedt,^{147a,147b} T. P. A. Åkesson,⁸¹ G. Akimoto,¹⁵⁶ A. V. Akimov,⁹⁶ G. L. Alberghi,^{20a,20b} J. Albert,¹⁷⁰ S. Albrand,⁵⁵ M. J. Alconada Verzini,⁷¹ M. Aleksa,³⁰ I. N. Aleksandrov,⁶⁵ C. Alexa,^{26a} G. Alexander,¹⁵⁴ G. Alexandre,⁴⁹ T. Alexopoulos,¹⁰ M. Alhroob,¹¹³ G. Alimonti,^{91a} L. Alio,⁸⁵ J. Alison,³¹ B. M. M. Allbrooke,¹⁸ L. J. Allison,⁷² P. P. Allport,⁷⁴ A. Aloisio,^{104a,104b} A. Alonso,³⁶ F. Alonso,⁷¹ C. Alpigiani,⁷⁶ A. Altheimer,³⁵ B. Alvarez Gonzalez,⁹⁰ M. G. Alviggi,^{104a,104b} K. Amako,⁶⁶ Y. Amaral Coutinho,^{24a} C. Amelung,²³ D. Amidei,⁸⁹ S. P. Amor Dos Santos,^{126a,126c} A. Amorim,^{126a,126b} S. Amoroso,⁴⁸ N. Amram,¹⁵⁴ G. Amundsen,²³ C. Anastopoulos,¹⁴⁰ L. S. Ancu,⁴⁹ N. Andari,³⁰ T. Andeen,³⁵ C. F. Anders,^{58b} G. Anders,³⁰ K. J. Anderson,³¹ A. Andreazza,^{91a,91b} V. Andrei,^{58a} X. S. Anduaga,⁷¹ S. Angelidakis,⁹ I. Angelozzi,¹⁰⁷ P. Anger,⁴⁴ A. Angerami,³⁵ F. Anghinolfi,³⁰ A. V. Anisenkov,^{109,d} N. Anjos,¹² A. Annovi,^{124a,124b} M. Antonelli,⁴⁷ A. Antonov,⁹⁸ J. Antos,^{145b} F. Anulli,^{133a} M. Aoki,⁶⁶ L. Aperio Bella,¹⁸ G. Arabidze,⁹⁰ Y. Arai,⁶⁶ J. P. Araque,^{126a} A. T. H. Arce,⁴⁵ F. A. Arduh,⁷¹ J-F. Arguin,⁹⁵ S. Argyropoulos,⁴² M. Arik,^{19a} A. J. Armbruster,³⁰ O. Arnaez,³⁰ V. Arnal,⁸² H. Arnold,⁴⁸ M. Arratia,²⁸ O. Arslan,²¹ A. Artamonov,⁹⁷ G. Artoni,²³ S. Asai,¹⁵⁶ N. Asbah,⁴² A. Ashkenazi,¹⁵⁴ B. Åsman,^{147a,147b} L. Asquith,¹⁵⁰ K. Assamagan,²⁵ R. Astalos,^{145a} M. Atkinson,¹⁶⁶ N. B. Atlay,¹⁴² B. Auerbach,⁶ K. Augsten,¹²⁸ M. Auresseau,^{146b} G. Avolio,³⁰ B. Axen,¹⁵ M. K. Ayoub,¹¹⁷ G. Azuelos,^{95,e} M. A. Baak,³⁰ A. E. Baas,^{58a} C. Bacci,^{135a,135b} H. Bachacou,¹³⁷ K. Bachas,¹⁵⁵ M. Backes,³⁰ M. Backhaus,³⁰ P. Bagiacchi,^{133a,133b} P. Bagnaia,^{133a,133b} Y. Bai,^{33a} T. Bain,³⁵ J. T. Baines,¹³¹ O. K. Baker,¹⁷⁷ P. Balek,¹²⁹ T. Balestri,¹⁴⁹ F. Balli,⁸⁴ E. Banas,³⁹ Sw. Banerjee,¹⁷⁴ A. A. E. Bannoura,¹⁷⁶ H. S. Bansil,¹⁸ L. Barak,³⁰ S. P. Baranov,⁹⁶ E. L. Barberio,⁸⁸ D. Barberis,^{50a,50b} M. Barbero,⁸⁵ T. Barillari,¹⁰¹ M. Barisonzi,^{165a,165b} T. Barklow,¹⁴⁴ N. Barlow,²⁸ S. L. Barnes,⁸⁴ B. M. Barnett,¹³¹ R. M. Barnett,¹⁵ Z. Barnovska,⁵ A. Baroncelli,^{135a} G. Barone,⁴⁹ A. J. Barr,¹²⁰ F. Barreiro,⁸² J. Barreiro Guimarães da Costa,⁵⁷ R. Bartoldus,¹⁴⁴ A. E. Barton,⁷² P. Bartos,^{145a} A. Bassalat,¹¹⁷ A. Basye,¹⁶⁶ R. L. Bates,⁵³ S. J. Batista,¹⁵⁹ J. R. Batley,²⁸ M. Battaglia,¹³⁸ M. Bause,^{133a,133b} F. Bauer,¹³⁷ H. S. Bawa,^{144,f} J. B. Beacham,¹¹¹ M. D. Beattie,⁷² T. Beau,⁸⁰ P. H. Beauchemin,¹⁶² R. Beccherle,^{124a,124b} P. Bechtel,²¹ H. P. Beck,^{17,g} K. Becker,¹²⁰ S. Becker,¹⁰⁰ M. Beckingham,¹⁷¹ C. Becot,¹¹⁷ A. J. Beddall,^{19c} A. Beddall,^{19c} V. A. Bednyakov,⁶⁵ C. P. Bee,¹⁴⁹ L. J. Beemster,¹⁰⁷ T. A. Beermann,¹⁷⁶ M. Begel,²⁵ K. Behr,¹²⁰ C. Belanger-Champagne,⁸⁷ P. J. Bell,⁴⁹ W. H. Bell,⁴⁹ G. Bella,¹⁵⁴ L. Bellagamba,^{20a} A. Bellerive,²⁹ M. Bellomo,⁸⁶ K. Belotskiy,⁹⁸ O. Beltramello,³⁰ O. Benary,¹⁵⁴ D. Benchekroun,^{136a} M. Bender,¹⁰⁰ K. Bendtz,^{147a,147b} N. Benekos,¹⁰ Y. Benhammou,¹⁵⁴ E. Benhar Noccioli,⁴⁹ J. A. Benitez Garcia,^{160b} D. P. Benjamin,⁴⁵ J. R. Bensinger,²³ S. Bentvelsen,¹⁰⁷ L. Beresford,¹²⁰ M. Beretta,⁴⁷ D. Berge,¹⁰⁷ E. Bergeas Kuutmann,¹⁶⁷ N. Berger,⁵ F. Berghaus,¹⁷⁰

- J. Beringer,¹⁵ C. Bernard,²² N. R. Bernard,⁸⁶ C. Bernius,¹¹⁰ F. U. Bernlochner,²¹ T. Berry,⁷⁷ P. Berta,¹²⁹ C. Bertella,⁸³
 G. Bertoli,^{147a,147b} F. Bertolucci,^{124a,124b} C. Bertsche,¹¹³ D. Bertsche,¹¹³ M. I. Besana,^{91a} G. J. Besjes,¹⁰⁶
 O. Bessidskaia Bylund,^{147a,147b} M. Bessner,⁴² N. Besson,¹³⁷ C. Betancourt,⁴⁸ S. Bethke,¹⁰¹ A. J. Bevan,⁷⁶ W. Bhimji,⁴⁶
 R. M. Bianchi,¹²⁵ L. Bianchini,²³ M. Bianco,³⁰ O. Biebel,¹⁰⁰ S. P. Bieniek,⁷⁸ M. Biglietti,^{135a} J. Bilbao De Mendizabal,⁴⁹
 H. Bilokon,⁴⁷ M. Bindi,⁵⁴ S. Binet,¹¹⁷ A. Bingul,^{19c} C. Bini,^{133a,133b} C. W. Black,¹⁵¹ J. E. Black,¹⁴⁴ K. M. Black,²²
 D. Blackburn,¹³⁹ R. E. Blair,⁶ J.-B. Blanchard,¹³⁷ J. E. Blanco,⁷⁷ T. Blazek,^{145a} I. Bloch,⁴² C. Blocker,²³ W. Blum,^{83,a}
 U. Blumenschein,⁵⁴ G. J. Bobbink,¹⁰⁷ V. S. Bobrovnikov,^{109,d} S. S. Bocchetta,⁸¹ A. Bocci,⁴⁵ C. Bock,¹⁰⁰ M. Boehler,⁴⁸
 J. A. Bogaerts,³⁰ A. G. Bogdanchikov,¹⁰⁹ C. Bohm,^{147a} V. Boisvert,⁷⁷ T. Bold,^{38a} V. Boldea,^{26a} A. S. Boldyrev,⁹⁹
 M. Bomben,⁸⁰ M. Bona,⁷⁶ M. Boonekamp,¹³⁷ A. Borisov,¹³⁰ G. Borissov,⁷² S. Borroni,⁴² J. Bortfeldt,¹⁰⁰
 V. Bortolotto,^{60a,60b,60c} K. Bos,¹⁰⁷ D. Boscherini,^{20a} M. Bosman,¹² J. Boudreau,¹²⁵ J. Bouffard,² E. V. Bouhova-Thacker,⁷²
 D. Boumediene,³⁴ C. Bourdarios,¹¹⁷ N. Bousson,¹¹⁴ S. Boutouil,^{136d} A. Boveia,³⁰ J. Boyd,³⁰ I. R. Boyko,⁶⁵ I. Bozic,¹³
 J. Bracinik,¹⁸ A. Brandt,⁸ G. Brandt,¹⁵ O. Brandt,^{58a} U. Bratzler,¹⁵⁷ B. Brau,⁸⁶ J. E. Brau,¹¹⁶ H. M. Braun,^{176,a}
 S. F. Brazzale,^{165a,165c} K. Brendlinger,¹²² A. J. Brennan,⁸⁸ L. Brenner,¹⁰⁷ R. Brenner,¹⁶⁷ S. Bressler,¹⁷³ K. Bristow,^{146c}
 T. M. Bristow,⁴⁶ D. Britton,⁵³ D. Britzger,⁴² F. M. Brochu,²⁸ I. Brock,²¹ R. Brock,⁹⁰ J. Bronner,¹⁰¹ G. Brooijmans,³⁵
 T. Brooks,⁷⁷ W. K. Brooks,^{32b} J. Brosamer,¹⁵ E. Brost,¹¹⁶ J. Brown,⁵⁵ P. A. Bruckman de Renstrom,³⁹ D. Bruncko,^{145b}
 R. Bruneliere,⁴⁸ A. Bruni,^{20a} G. Bruni,^{20a} M. Bruschi,^{20a} L. Bryngemark,⁸¹ T. Buanes,¹⁴ Q. Buat,¹⁴³ F. Bucci,⁴⁹
 P. Buchholz,¹⁴² A. G. Buckley,⁵³ S. I. Buda,^{26a} I. A. Budagov,⁶⁵ F. Buehrer,⁴⁸ L. Bugge,¹¹⁹ M. K. Bugge,¹¹⁹ O. Bulekov,⁹⁸
 H. Burckhart,³⁰ S. Burdin,⁷⁴ B. Burghgrave,¹⁰⁸ S. Burke,¹³¹ I. Burmeister,⁴³ E. Busato,³⁴ D. Büscher,⁴⁸ V. Büscher,⁸³
 P. Bussey,⁵³ C. P. Buszello,¹⁶⁷ J. M. Butler,²² A. I. Butt,³ C. M. Buttar,⁵³ J. M. Butterworth,⁷⁸ P. Butti,¹⁰⁷ W. Buttinger,²⁵
 A. Buzatu,⁵³ S. Cabrera Urbán,¹⁶⁸ D. Caforio,¹²⁸ O. Cakir,^{4a} P. Calafiura,¹⁵ A. Calandri,¹³⁷ G. Calderini,⁸⁰ P. Calfayan,¹⁰⁰
 L. P. Caloba,^{24a} D. Calvet,³⁴ S. Calvet,³⁴ R. Camacho Toro,⁴⁹ S. Camarda,⁴² D. Cameron,¹¹⁹ L. M. Caminada,¹⁵
 R. Caminal Armadans,¹² S. Campana,³⁰ M. Campanelli,⁷⁸ A. Campoverde,¹⁴⁹ V. Canale,^{104a,104b} A. Canepa,^{160a}
 M. Cano Bret,⁷⁶ J. Cantero,⁸² R. Cantrill,^{126a} T. Cao,⁴⁰ M. D. M. Capeans Garrido,³⁰ I. Caprini,^{26a} M. Caprini,^{26a}
 M. Capua,^{37a,37b} R. Caputo,⁸³ R. Cardarelli,^{134a} T. Carli,³⁰ G. Carlino,^{104a} L. Carminati,^{91a,91b} S. Caron,¹⁰⁶ E. Carquin,^{32a}
 G. D. Carrillo-Montoya,⁸ J. R. Carter,²⁸ J. Carvalho,^{126a,126c} D. Casadei,⁷⁸ M. P. Casado,¹² M. Casolino,¹²
 E. Castaneda-Miranda,^{146b} A. Castelli,¹⁰⁷ V. Castillo Gimenez,¹⁶⁸ N. F. Castro,^{126a} P. Catastini,⁵⁷ A. Catinaccio,³⁰
 J. R. Catmore,¹¹⁹ A. Cattai,³⁰ G. Cattani,^{134a,134b} J. Caudron,⁸³ V. Cavaliere,¹⁶⁶ D. Cavalli,^{91a} M. Cavalli-Sforza,¹²
 V. Cavasinni,^{124a,124b} F. Ceradini,^{135a,135b} B. C. Cerio,⁴⁵ K. Cerny,¹²⁹ A. S. Cerqueira,^{24b} A. Cerri,¹⁵⁰ L. Cerrito,⁷⁶ F. Cerutti,¹⁵
 M. Cerv,³⁰ A. Cervelli,¹⁷ S. A. Cetin,^{19b} A. Chafaq,^{136a} D. Chakraborty,¹⁰⁸ I. Chalupkova,¹²⁹ P. Chang,¹⁶⁶ B. Chapleau,⁸⁷
 J. D. Chapman,²⁸ D. Charfeddine,¹¹⁷ D. G. Charlton,¹⁸ C. C. Chau,¹⁵⁹ C. A. Chavez Barajas,¹⁵⁰ S. Cheatham,¹⁵³
 A. Chegwidan,⁹⁰ S. Chekanov,⁶ S. V. Chekulaev,^{160a} G. A. Chelkov,^{65,h} M. A. Chelstowska,⁸⁹ C. Chen,⁶⁴ H. Chen,²⁵
 K. Chen,¹⁴⁹ L. Chen,^{33d,i} S. Chen,^{33c} X. Chen,^{33f} Y. Chen,⁶⁷ H. C. Cheng,⁸⁹ Y. Cheng,³¹ A. Cheplakov,⁶⁵
 E. Cheremushkina,¹³⁰ R. Cherkaoui El Moursli,^{136e} V. Chernyatin,^{25,a} E. Cheu,⁷ L. Chevalier,¹³⁷ V. Chiarella,⁴⁷
 J. T. Childers,⁶ A. Chilingarov,⁷² G. Chiodini,^{73a} A. S. Chisholm,¹⁸ R. T. Chislett,⁷⁸ A. Chitan,^{26a} M. V. Chizhov,⁶⁵
 K. Choi,⁶¹ S. Chouridou,⁹ B. K. B. Chow,¹⁰⁰ V. Christodoulou,⁷⁸ D. Chromek-Burckhart,³⁰ M. L. Chu,¹⁵² J. Chudoba,¹²⁷
 J. J. Chwastowski,³⁹ L. Chytka,¹¹⁵ G. Ciapetti,^{133a,133b} A. K. Ciftci,^{4a} D. Cinca,⁵³ V. Cindro,⁷⁵ A. Ciocio,¹⁵ Z. H. Citron,¹⁷³
 M. Ciubancan,^{26a} A. Clark,⁴⁹ P. J. Clark,⁴⁶ R. N. Clarke,¹⁵ W. Cleland,¹²⁵ C. Clement,^{147a,147b} Y. Coadou,⁸⁵ M. Cobal,^{165a,165c}
 A. Cocco,¹³⁹ J. Cochran,⁶⁴ L. Coffey,²³ J. G. Cogan,¹⁴⁴ B. Cole,³⁵ S. Cole,¹⁰⁸ A. P. Colijn,¹⁰⁷ J. Collot,⁵⁵ T. Colombo,^{58c}
 G. Compostella,¹⁰¹ P. Conde Muiño,^{126a,126b} E. Coniavitis,⁴⁸ S. H. Connell,^{146b} I. A. Connelly,⁷⁷ S. M. Consonni,^{91a,91b}
 V. Consorti,⁴⁸ S. Constantinescu,^{26a} C. Conta,^{121a,121b} G. Conti,³⁰ F. Conventi,^{104a,j} M. Cooke,¹⁵ B. D. Cooper,⁷⁸
 A. M. Cooper-Sarkar,¹²⁰ K. Copic,¹⁵ T. Cornelissen,¹⁷⁶ M. Corradi,^{20a} F. Corriveau,^{87,k} A. Corso-Radu,¹⁶⁴
 A. Cortes-Gonzalez,¹² G. Cortiana,¹⁰¹ M. J. Costa,¹⁶⁸ D. Costanzo,¹⁴⁰ D. Côté,⁸ G. Cottin,²⁸ G. Cowan,⁷⁷ B. E. Cox,⁸⁴
 K. Cranmer,¹¹⁰ G. Cree,²⁹ S. Crépe-Renaudin,⁵⁵ F. Crescioli,⁸⁰ W. A. Cribbs,^{147a,147b} M. Crispin Ortuzar,¹²⁰
 M. Cristinziani,²¹ V. Croft,¹⁰⁶ G. Crosetti,^{37a,37b} T. Cuhadar Donszelmann,¹⁴⁰ J. Cummings,¹⁷⁷ M. Curatolo,⁴⁷ C. Cuthbert,¹⁵¹
 H. Czirr,¹⁴² P. Czodrowski,³ S. D'Auria,⁵³ M. D'Onofrio,⁷⁴ M. J. Da Cunha Sargedas De Sousa,^{126a,126b} C. Da Via,⁸⁴
 W. Dabrowski,^{38a} A. Dainca,¹²⁰ T. Dai,⁸⁹ O. Dale,¹⁴ F. Dallaire,⁹⁵ C. Dallapiccola,⁸⁶ M. Dam,³⁶ J. R. Dandoy,³¹
 A. C. Daniells,¹⁸ M. Danninger,¹⁶⁹ M. Dano Hoffmann,¹³⁷ V. Dao,⁴⁸ G. Darbo,^{50a} S. Darmora,⁸ J. Dassoulas,³
 A. Dattagupta,⁶¹ W. Davey,²¹ C. David,¹⁷⁰ T. Davidek,¹²⁹ E. Davies,^{120,l} M. Davies,¹⁵⁴ O. Davignon,⁸⁰ P. Davison,⁷⁸
 Y. Davygora,^{58a} E. Dawe,¹⁴³ I. Dawson,¹⁴⁰ R. K. Daya-Ishmukhametova,⁸⁶ K. De,⁸ R. de Asmundis,^{104a} S. De Castro,^{20a,20b}

- S. De Cecco,⁸⁰ N. De Groot,¹⁰⁶ P. de Jong,¹⁰⁷ H. De la Torre,⁸² F. De Lorenzi,⁶⁴ L. De Nooij,¹⁰⁷ D. De Pedis,^{133a}
A. De Salvo,^{133a} U. De Sanctis,¹⁵⁰ A. De Santo,¹⁵⁰ J. B. De Vivie De Regie,¹¹⁷ W. J. Dearnaley,⁷² R. Debbe,²⁵
C. Debenedetti,¹³⁸ D. V. Dedovich,⁶⁵ I. Deigaard,¹⁰⁷ J. Del Peso,⁸² T. Del Prete,^{124a,124b} D. Delgove,¹¹⁷ F. Deliot,¹³⁷
C. M. Delitzsch,⁴⁹ M. Deliyergiyev,⁷⁵ A. Dell'Acqua,³⁰ L. Dell'Asta,²² M. Dell'Orso,^{124a,124b} M. Della Pietra,^{104a,j}
D. della Volpe,⁴⁹ M. Delmastro,⁵ P. A. Delsart,⁵⁵ C. Deluca,¹⁰⁷ D. A. DeMarco,¹⁵⁹ S. Demers,¹⁷⁷ M. Demichev,⁶⁵
A. Demilly,⁸⁰ S. P. Denisov,¹³⁰ D. Derendarz,³⁹ J. E. Derkaoui,^{136d} F. Derue,⁸⁰ P. Dervan,⁷⁴ K. Desch,²¹ C. Deterre,⁴²
P. O. Deviveiros,³⁰ A. Dewhurst,¹³¹ S. Dhaliwal,¹⁰⁷ A. Di Ciaccio,^{134a,134b} L. Di Ciaccio,⁵ A. Di Domenico,^{133a,133b}
C. Di Donato,^{104a,104b} A. Di Girolamo,³⁰ B. Di Girolamo,³⁰ A. Di Mattia,¹⁵³ B. Di Micco,^{135a,135b} R. Di Nardo,⁴⁷
A. Di Simone,⁴⁸ R. Di Sipio,¹⁵⁹ D. Di Valentino,²⁹ C. Diaconu,⁸⁵ M. Diamond,¹⁵⁹ F. A. Dias,⁴⁶ M. A. Diaz,^{32a} E. B. Diehl,⁸⁹
J. Dietrich,¹⁶ S. Diglio,⁸⁵ A. Dimitrievska,¹³ J. Dingfelder,²¹ F. Dittus,³⁰ F. Djama,⁸⁵ T. Djobava,^{51b} J. I. Djuvsland,^{58a}
M. A. B. do Vale,^{24c} D. Dobos,³⁰ M. Dobre,^{26a} C. Doglioni,⁴⁹ T. Dohmae,¹⁵⁶ J. Dolejsi,¹²⁹ Z. Dolezal,¹²⁹
B. A. Dolgoshein,^{98,a} M. Donadelli,^{24d} S. Donati,^{124a,124b} P. Dondero,^{121a,121b} J. Donini,³⁴ J. Dopke,¹³¹ A. Doria,^{104a}
M. T. Dova,⁷¹ A. T. Doyle,⁵³ M. Dris,¹⁰ E. Dubreuil,³⁴ E. Duchovni,¹⁷³ G. Duckeck,¹⁰⁰ O. A. Ducu,^{26a,85} D. Duda,¹⁷⁶
A. Dudarev,³⁰ L. Duflot,¹¹⁷ L. Duguid,⁷⁷ M. Dührssen,³⁰ M. Dunford,^{58a} H. Duran Yildiz,^{4a} M. Düren,⁵² A. Durglishvili,^{51b}
D. Duschinger,⁴⁴ M. Dwuznik,^{38a} M. Dyndal,^{38a} K. M. Ecker,¹⁰¹ W. Edson,² N. C. Edwards,⁴⁶ W. Ehrenfeld,²¹ T. Eifert,³⁰
G. Eigen,¹⁴ K. Einsweiler,¹⁵ T. Ekelof,¹⁶⁷ M. El Kacimi,^{136c} M. Ellert,¹⁶⁷ S. Elles,⁵ F. Ellinghaus,⁸³ A. A. Elliot,¹⁷⁰ N. Ellis,³⁰
J. Elmsheuser,¹⁰⁰ M. Elsing,³⁰ D. Emelianov,¹³¹ Y. Enari,¹⁵⁶ O. C. Endner,⁸³ M. Endo,¹¹⁸ R. Engelmann,¹⁴⁹ J. Erdmann,⁴³
A. Ereditato,¹⁷ D. Eriksson,^{147a} G. Ernis,¹⁷⁶ J. Ernst,² M. Ernst,²⁵ S. Errede,¹⁶⁶ E. Ertel,⁸³ M. Escalier,¹¹⁷ H. Esch,⁴³
C. Escobar,¹²⁵ B. Esposito,⁴⁷ A. I. Etienne,¹³⁷ E. Etzion,¹⁵⁴ H. Evans,⁶¹ A. Ezhilov,¹²³ L. Fabbri,^{20a,20b} G. Facini,³¹
R. M. Fakhrutdinov,¹³⁰ S. Falciano,^{133a} R. J. Falla,⁷⁸ J. Faltova,¹²⁹ Y. Fang,^{33a} M. Fanti,^{91a,91b} A. Farbin,⁸ A. Farilla,^{135a}
T. Farooque,¹² S. Farrell,¹⁵ S. M. Farrington,¹⁷¹ P. Farthouat,³⁰ F. Fassi,^{136e} P. Fassnacht,³⁰ D. Fassouliotis,⁹
A. Favareto,^{50a,50b} L. Fayard,¹¹⁷ P. Federic,^{145a} O. L. Fedin,^{123,m} W. Fedorko,¹⁶⁹ S. Feigl,³⁰ L. Feligioni,⁸⁵ C. Feng,^{33d}
E. J. Feng,⁶ H. Feng,⁸⁹ A. B. Fenyuk,¹³⁰ P. Fernandez Martinez,¹⁶⁸ S. Fernandez Perez,³⁰ S. Ferrag,⁵³ J. Ferrando,⁵³
A. Ferrari,¹⁶⁷ P. Ferrari,¹⁰⁷ R. Ferrari,^{121a} D. E. Ferreira de Lima,⁵³ A. Ferrer,¹⁶⁸ D. Ferrere,⁴⁹ C. Ferretti,⁸⁹
A. Ferretto Parodi,^{50a,50b} M. Fiascaris,³¹ F. Fiedler,⁸³ A. Filipčič,⁷⁵ M. Filipuzzi,⁴² F. Filthaut,¹⁰⁶ M. Fincke-Keeler,¹⁷⁰
K. D. Finelli,¹⁵¹ M. C. N. Fiolhais,^{126a,126c} L. Fiorini,¹⁶⁸ A. Firan,⁴⁰ A. Fischer,² C. Fischer,¹² J. Fischer,¹⁷⁶ W. C. Fisher,⁹⁰
E. A. Fitzgerald,²³ M. Flechl,⁴⁸ I. Fleck,¹⁴² P. Fleischmann,⁸⁹ S. Fleischmann,¹⁷⁶ G. T. Fletcher,¹⁴⁰ G. Fletcher,⁷⁶ T. Flick,¹⁷⁶
A. Floderus,⁸¹ L. R. Flores Castillo,^{60a} M. J. Flowerdew,¹⁰¹ A. Formica,¹³⁷ A. Forti,⁸⁴ D. Fournier,¹¹⁷ H. Fox,⁷² S. Fracchia,¹²
P. Francavilla,⁸⁰ M. Franchini,^{20a,20b} D. Francis,³⁰ L. Franconi,¹¹⁹ M. Franklin,⁵⁷ M. Fraternali,^{121a,121b} D. Freeborn,⁷⁸
S. T. French,²⁸ F. Friedrich,⁴⁴ D. Froidevaux,³⁰ J. A. Frost,¹²⁰ C. Fukunaga,¹⁵⁷ E. Fullana Torregrosa,⁸³ B. G. Fulsom,¹⁴⁴
J. Fuster,¹⁶⁸ C. Gabaldon,⁵⁵ O. Gabizon,¹⁷⁶ A. Gabrielli,^{20a,20b} A. Gabrielli,^{133a,133b} S. Gadatsch,¹⁰⁷ S. Gadomski,⁴⁹
G. Gagliardi,^{50a,50b} P. Gagnon,⁶¹ C. Galea,¹⁰⁶ B. Galhardo,^{126a,126c} E. J. Gallas,¹²⁰ B. J. Gallop,¹³¹ P. Gallus,¹²⁸ G. Galster,³⁶
K. K. Gan,¹¹¹ J. Gao,^{33b,85} Y. S. Gao,^{144,f} F. M. Garay Walls,⁴⁶ F. Garbersen,¹⁷⁷ C. García,¹⁶⁸ J. E. García Navarro,¹⁶⁸
M. Garcia-Sciveres,¹⁵ R. W. Gardner,³¹ N. Garelli,¹⁴⁴ V. Garonne,³⁰ C. Gatti,⁴⁷ G. Gaudio,^{121a} B. Gaur,¹⁴² L. Gauthier,⁹⁵
P. Gauzzi,^{133a,133b} I. L. Gavrilenko,⁹⁶ C. Gay,¹⁶⁹ G. Gaycken,²¹ E. N. Gazis,¹⁰ P. Ge,^{33d} Z. Gecse,¹⁶⁹ C. N. P. Gee,¹³¹
D. A. A. Geerts,¹⁰⁷ Ch. Geich-Gimbel,²¹ C. Gemme,^{50a} M. H. Genest,⁵⁵ S. Gentile,^{133a,133b} M. George,⁵⁴ S. George,⁷⁷
D. Gerbaudo,¹⁶⁴ A. Gershon,¹⁵⁴ H. Ghazlane,^{136b} N. Ghodbane,³⁴ B. Giacobbe,^{20a} S. Giagu,^{133a,133b} V. Giangiobbe,¹²
P. Giannetti,^{124a,124b} F. Gianotti,³⁰ B. Gibbard,²⁵ S. M. Gibson,⁷⁷ M. Gilchriese,¹⁵ T. P. S. Gillam,²⁸ D. Gillberg,³⁰ G. Gilles,³⁴
D. M. Gingrich,^{3,e} N. Giokaris,⁹ M. P. Giordani,^{165a,165c} F. M. Giorgi,^{20a} F. M. Giorgi,¹⁶ P. F. Giraud,¹³⁷ P. Giromini,⁴⁷
D. Giugni,^{91a} C. Giuliani,⁴⁸ M. Giulini,^{58b} B. K. Gjelsten,¹¹⁹ S. Gkaitatzis,¹⁵⁵ I. Gkialas,¹⁵⁵ E. L. Gkoukousis,¹¹⁷
L. K. Gladilin,⁹⁹ C. Glasman,⁸² J. Glatzer,³⁰ P. C. F. Glaysher,⁴⁶ A. Glazov,⁴² M. Goblirsch-Kolb,¹⁰¹ J. R. Goddard,⁷⁶
J. Godlewski,³⁹ S. Goldfarb,⁸⁹ T. Golling,⁴⁹ D. Golubkov,¹³⁰ A. Gomes,^{126a,126b,126d} R. Gonçalves,^{126a}
J. Goncalves Pinto Firmino Da Costa,¹³⁷ L. Gonella,²¹ S. González de la Hoz,¹⁶⁸ G. Gonzalez Parra,¹² S. Gonzalez-Sevilla,⁴⁹
L. Goossens,³⁰ P. A. Gorbounov,⁹⁷ H. A. Gordon,²⁵ I. Gorelov,¹⁰⁵ B. Gorini,³⁰ E. Gorini,^{73a,73b} A. Gorišek,⁷⁵ E. Gornicki,³⁹
A. T. Goshaw,⁴⁵ C. Gössling,⁴³ M. I. Gostkin,⁶⁵ M. Gouighri,^{136a} D. Goujdami,^{136c} A. G. Goussiou,¹³⁹ H. M. X. Grabas,¹³⁸
L. Graber,⁵⁴ I. Grabowska-Bold,^{38a} P. Grafström,^{20a,20b} K.-J. Grahn,⁴² J. Gramling,⁴⁹ E. Gramstad,¹¹⁹ S. Grancagnolo,¹⁶
V. Grassi,¹⁴⁹ V. Gratchev,¹²³ H. M. Gray,³⁰ E. Graziani,^{135a} Z. D. Greenwood,^{79,n} K. Gregersen,⁷⁸ I. M. Gregor,⁴²
P. Grenier,¹⁴⁴ J. Griffiths,⁸ A. A. Grillo,¹³⁸ K. Grimm,⁷² S. Grinstein,^{12,o} Ph. Gris,³⁴ Y. V. Grishkevich,⁹⁹ J.-F. Grivaz,¹¹⁷
J. P. Grohs,⁴⁴ A. Grohsjean,⁴² E. Gross,¹⁷³ J. Grosse-Knetter,⁵⁴ G. C. Grossi,^{134a,134b} Z. J. Grout,¹⁵⁰ L. Guan,^{33b}

J. Guenther,¹²⁸ F. Guescini,⁴⁹ D. Guest,¹⁷⁷ O. Gueta,¹⁵⁴ E. Guido,^{50a,50b} T. Guillemin,¹¹⁷ S. Guindon,² U. Gul,⁵³ C. Gumpert,⁴⁴ J. Guo,^{33e} S. Gupta,¹²⁰ P. Gutierrez,¹¹³ N. G. Gutierrez Ortiz,⁵³ C. Gutschow,⁴⁴ N. Guttman,¹⁵⁴ C. Guyot,¹³⁷ C. Gwenlan,¹²⁰ C. B. Gwilliam,⁷⁴ A. Haas,¹¹⁰ C. Haber,¹⁵ H. K. Hadavand,⁸ N. Haddad,^{136e} P. Haefner,²¹ S. Hageböck,²¹ Z. Hajduk,³⁹ H. Hakobyan,¹⁷⁸ M. Haleem,⁴² J. Haley,¹¹⁴ D. Hall,¹²⁰ G. Halladjian,⁹⁰ G. D. Hallewell,⁸⁵ K. Hamacher,¹⁷⁶ P. Hamal,¹¹⁵ K. Hamano,¹⁷⁰ M. Hamer,⁵⁴ A. Hamilton,^{146a} S. Hamilton,¹⁶² G. N. Hamity,^{146c} P. G. Hamnett,⁴² L. Han,^{33b} K. Hanagaki,¹¹⁸ K. Hanawa,¹⁵⁶ M. Hance,¹⁵ P. Hanke,^{58a} R. Hanna,¹³⁷ J. B. Hansen,³⁶ J. D. Hansen,³⁶ P. H. Hansen,³⁶ K. Hara,¹⁶¹ A. S. Hard,¹⁷⁴ T. Harenberg,¹⁷⁶ F. Hariri,¹¹⁷ S. Harkusha,⁹² R. D. Harrington,⁴⁶ P. F. Harrison,¹⁷¹ F. Hartjes,¹⁰⁷ M. Hasegawa,⁶⁷ S. Hasegawa,¹⁰³ Y. Hasegawa,¹⁴¹ A. Hasib,¹¹³ S. Hassani,¹³⁷ S. Haug,¹⁷ R. Hauser,⁹⁰ L. Hauswald,⁴⁴ M. Havranek,¹²⁷ C. M. Hawkes,¹⁸ R. J. Hawkings,³⁰ A. D. Hawkins,⁸¹ T. Hayashi,¹⁶¹ D. Hayden,⁹⁰ C. P. Hays,¹²⁰ J. M. Hays,⁷⁶ H. S. Hayward,⁷⁴ S. J. Haywood,¹³¹ S. J. Head,¹⁸ T. Heck,⁸³ V. Hedberg,⁸¹ L. Heelan,⁸ S. Heim,¹²² T. Heim,¹⁷⁶ B. Heinemann,¹⁵ L. Heinrich,¹¹⁰ J. Hejbal,¹²⁷ L. Helary,²² M. Heller,³⁰ S. Hellman,^{147a,147b} D. Hellmich,²¹ C. Helsens,³⁰ J. Henderson,¹²⁰ R. C. W. Henderson,⁷² Y. Heng,¹⁷⁴ C. Hengler,⁴² A. Henrichs,¹⁷⁷ A. M. Henriques Correia,³⁰ S. Henrot-Versille,¹¹⁷ G. H. Herbert,¹⁶ Y. Hernández Jiménez,¹⁶⁸ R. Herrberg-Schubert,¹⁶ G. Herten,⁴⁸ R. Hertenberger,¹⁰⁰ L. Hervas,³⁰ G. G. Hesketh,⁷⁸ N. P. Hessey,¹⁰⁷ R. Hickling,⁷⁶ E. Higón-Rodríguez,¹⁶⁸ E. Hill,¹⁷⁰ J. C. Hill,²⁸ K. H. Hiller,⁴² S. J. Hillier,¹⁸ I. Hinchliffe,¹⁵ E. Hines,¹²² R. R. Hinman,¹⁵ M. Hirose,¹⁵⁸ D. Hirschbuehl,¹⁷⁶ J. Hobbs,¹⁴⁹ N. Hod,¹⁰⁷ M. C. Hodgkinson,¹⁴⁰ P. Hodgson,¹⁴⁰ A. Hoecker,³⁰ M. R. Hoferkamp,¹⁰⁵ F. Hoenig,¹⁰⁰ M. Hohlfield,⁸³ D. Hohn,²¹ T. R. Holmes,¹⁵ T. M. Hong,¹²² L. Hooft van Huysduynen,¹¹⁰ W. H. Hopkins,¹¹⁶ Y. Horii,¹⁰³ A. J. Horton,¹⁴³ J.-Y. Hostachy,⁵⁵ S. Hou,¹⁵² A. Hoummada,^{136a} J. Howard,¹²⁰ J. Howarth,⁴² M. Hrabovsky,¹¹⁵ I. Hristova,¹⁶ J. Hrivnac,¹¹⁷ T. Hryn'ova,⁵ A. Hrynevich,⁹³ C. Hsu,^{146c} P. J. Hsu,^{152,p} S.-C. Hsu,¹³⁹ D. Hu,³⁵ Q. Hu,^{33b} X. Hu,⁸⁹ Y. Huang,⁴² Z. Hubacek,³⁰ F. Hubaut,⁸⁵ F. Huegging,²¹ T. B. Huffman,¹²⁰ E. W. Hughes,³⁵ G. Hughes,⁷² M. Huhtinen,³⁰ T. A. Hülsing,⁸³ N. Huseynov,^{65,c} J. Huston,⁹⁰ J. Huth,⁵⁷ G. Iacobucci,⁴⁹ G. Iakovidis,²⁵ I. Ibragimov,¹⁴² L. Iconomidou-Fayard,¹¹⁷ E. Ideal,¹⁷⁷ Z. Idrissi,^{136e} P. Iengo,^{104a} O. Igonkina,¹⁰⁷ T. Iizawa,¹⁷² Y. Ikegami,⁶⁶ K. Ikematsu,¹⁴² M. Ikeno,⁶⁶ Y. Ilchenko,^{31,q} D. Iliadis,¹⁵⁵ N. Ilic,¹⁵⁹ Y. Inamaru,⁶⁷ T. Ince,¹⁰¹ P. Ioannou,⁹ M. Iodice,^{135a} K. Iordanidou,⁹ V. Ippolito,⁵⁷ A. Irles Quiles,¹⁶⁸ C. Isaksson,¹⁶⁷ M. Ishino,⁶⁸ M. Ishitsuka,¹⁵⁸ R. Ishmukhametov,¹¹¹ C. Issever,¹²⁰ S. Istin,^{19a} J. M. Iturbe Ponce,⁸⁴ R. Iuppa,^{134a,134b} J. Ivarsson,⁸¹ W. Iwanski,³⁹ H. Iwasaki,⁶⁶ J. M. Izen,⁴¹ V. Izzo,^{104a} S. Jabbar,³ B. Jackson,¹²² M. Jackson,⁷⁴ P. Jackson,¹ M. R. Jaekel,³⁰ V. Jain,² K. Jakobs,⁴⁸ S. Jakobsen,³⁰ T. Jakoubek,¹²⁷ J. Jakubek,¹²⁸ D. O. Jamin,¹⁵² D. K. Jana,⁷⁹ E. Jansen,⁷⁸ R. W. Jansky,⁶² J. Janssen,²¹ M. Janus,¹⁷¹ G. Jarlskog,⁸¹ N. Javadov,^{65,c} T. Javůrek,⁴⁸ L. Jeanty,¹⁵ J. Jejelava,^{51a,r} G.-Y. Jeng,¹⁵¹ D. Jennens,⁸⁸ P. Jenni,^{48,s} J. Jentzsch,⁴³ C. Jeske,¹⁷¹ S. Jézéquel,⁵ H. Ji,¹⁷⁴ J. Jia,¹⁴⁹ Y. Jiang,^{33b} J. Jimenez Pena,¹⁶⁸ S. Jin,^{33a} A. Jinaru,^{26a} O. Jinnouchi,¹⁵⁸ M. D. Joergensen,³⁶ P. Johansson,¹⁴⁰ K. A. Johns,⁷ K. Jon-And,^{147a,147b} G. Jones,¹⁷¹ R. W. L. Jones,⁷² T. J. Jones,⁷⁴ J. Jongmanns,^{58a} P. M. Jorge,^{126a,126b} K. D. Joshi,⁸⁴ J. Jovicevic,¹⁴⁸ X. Ju,¹⁷⁴ C. A. Jung,⁴³ P. Jussel,⁶² A. Juste Rozas,^{12,o} M. Kaci,¹⁶⁸ A. Kaczmarska,³⁹ M. Kado,¹¹⁷ H. Kagan,¹¹¹ M. Kagan,¹⁴⁴ S. J. Kahn,⁸⁵ E. Kajomovitz,⁴⁵ C. W. Kalderon,¹²⁰ S. Kama,⁴⁰ A. Kamenshchikov,¹³⁰ N. Kanaya,¹⁵⁶ M. Kaneda,³⁰ S. Kaneti,²⁸ V. A. Kantserov,⁹⁸ J. Kanzaki,⁶⁶ B. Kaplan,¹¹⁰ A. Kapliy,³¹ D. Kar,⁵³ K. Karakostas,¹⁰ A. Karamaoun,³ N. Karastathis,^{10,107} M. J. Kareem,⁵⁴ M. Karnevskiy,⁸³ S. N. Karpov,⁶⁵ Z. M. Karpova,⁶⁵ K. Karthik,¹¹⁰ V. Kartvelishvili,⁷² A. N. Karyukhin,¹³⁰ L. Kashif,¹⁷⁴ R. D. Kass,¹¹¹ A. Kastanas,¹⁴ Y. Kataoka,¹⁵⁶ A. Katre,⁴⁹ J. Katzy,⁴² K. Kawagoe,⁷⁰ T. Kawamoto,¹⁵⁶ G. Kawamura,⁵⁴ S. Kazama,¹⁵⁶ V. F. Kazanin,^{109,d} M. Y. Kazarinov,⁶⁵ R. Keeler,¹⁷⁰ R. Kehoe,⁴⁰ M. Keil,⁵⁴ J. S. Keller,⁴² J. J. Kempster,⁷⁷ H. Keoshkerian,⁸⁴ O. Kepka,¹²⁷ B. P. Kerševan,⁷⁵ S. Kersten,¹⁷⁶ R. A. Keyes,⁸⁷ F. Khalil-zada,¹¹ H. Khandanyan,^{147a,147b} A. Khanov,¹¹⁴ A. Kharlamov,¹⁰⁹ A. Khodinov,⁹⁸ T. J. Khoo,²⁸ G. Khorauli,²¹ V. Khovanskiy,⁹⁷ E. Khramov,⁶⁵ J. Khubua,^{51b,t} H. Y. Kim,⁸ H. Kim,^{147a,147b} S. H. Kim,¹⁶¹ Y. Kim,³¹ N. Kimura,¹⁵⁵ O. M. Kind,¹⁶ B. T. King,⁷⁴ M. King,¹⁶⁸ R. S. B. King,¹²⁰ S. B. King,¹⁶⁹ J. Kirk,¹³¹ A. E. Kiryunin,¹⁰¹ T. Kishimoto,⁶⁷ D. Kisielewska,^{38a} F. Kiss,⁴⁸ K. Kiuchi,¹⁶¹ E. Kladiva,^{145b} M. H. Klein,³⁵ M. Klein,⁷⁴ U. Klein,⁷⁴ K. Kleinknecht,⁸³ P. Klimek,^{147a,147b} A. Klimentov,²⁵ R. Klingenberg,⁴³ J. A. Klinger,⁸⁴ T. Klioutchnikova,³⁰ P. F. Klok,¹⁰⁶ E.-E. Kluge,^{58a} P. Kluit,¹⁰⁷ S. Kluth,¹⁰¹ E. Kneringer,⁶² E. B. F. G. Knoop,⁸⁵ A. Knue,⁵³ D. Kobayashi,¹⁵⁸ T. Kobayashi,¹⁵⁶ M. Kobel,⁴⁴ M. Kocian,¹⁴⁴ P. Kodys,¹²⁹ T. Koffas,²⁹ E. Koffeman,¹⁰⁷ L. A. Kogan,¹²⁰ S. Kohlmann,¹⁷⁶ Z. Kohout,¹²⁸ T. Kohriki,⁶⁶ T. Koi,¹⁴⁴ H. Kolanoski,¹⁶ I. Koletsou,⁵ A. A. Komar,^{96,a} Y. Komori,¹⁵⁶ T. Kondo,⁶⁶ N. Kondrashova,⁴² K. Köneke,⁴⁸ A. C. König,¹⁰⁶ S. König,⁸³ T. Kono,^{66,u} R. Konoplich,^{110,v} N. Konstantinidis,⁷⁸ R. Kopeliansky,¹⁵³ S. Kopermy,^{38a} L. Köpke,⁸³ A. K. Kopp,⁴⁸ K. Korcyl,³⁹ K. Kordas,¹⁵⁵ A. Korn,⁷⁸ A. A. Korol,^{109,d} I. Korolkov,¹² E. V. Korolkova,¹⁴⁰ O. Kortner,¹⁰¹ S. Kortner,¹⁰¹ T. Kosek,¹²⁹ V. V. Kostyukhin,²¹ V. M. Kotov,⁶⁵ A. Kotwal,⁴⁵ A. Kourkouveli-Charalampidi,¹⁵⁵ C. Kourkouvelis,⁹ V. Kouskoura,²⁵ A. Koutsman,^{160a} R. Kowalewski,¹⁷⁰

- T. Z. Kowalski,^{38a} W. Kozanecki,¹³⁷ A. S. Kozhin,¹³⁰ V. A. Kramarenko,⁹⁹ G. Kramberger,⁷⁵ D. Krasnopevtsev,⁹⁸ M. W. Krasny,⁸⁰ A. Krasznahorkay,³⁰ J. K. Kraus,²¹ A. Kravchenko,²⁵ S. Kreiss,¹¹⁰ M. Kretz,^{58c} J. Kretzschmar,⁷⁴ K. Kreutzfeldt,⁵² P. Krieger,¹⁵⁹ K. Krizka,³¹ K. Kroeninger,⁴³ H. Kroha,¹⁰¹ J. Kroll,¹²² J. Kroseberg,²¹ J. Krstic,¹³ U. Kruchonak,⁶⁵ H. Krüger,²¹ N. Krumnack,⁶⁴ Z. V. Krumshcheyn,⁶⁵ A. Kruse,¹⁷⁴ M. C. Kruse,⁴⁵ M. Kruskal,²² T. Kubota,⁸⁸ H. Kucuk,⁷⁸ S. Kuday,^{4c} S. Kuehn,⁴⁸ A. Kugel,^{58c} F. Kuger,¹⁷⁵ A. Kuhl,¹³⁸ T. Kuhl,⁴² V. Kukhtin,⁶⁵ Y. Kulchitsky,⁹² S. Kuleshov,^{32b} M. Kuna,^{133a,133b} T. Kunigo,⁶⁸ A. Kupco,¹²⁷ H. Kurashige,⁶⁷ Y. A. Kurochkin,⁹² R. Kurumida,⁶⁷ V. Kus,¹²⁷ E. S. Kuwertz,¹⁴⁸ M. Kuze,¹⁵⁸ J. Kvita,¹¹⁵ T. Kwan,¹⁷⁰ D. Kyriazopoulos,¹⁴⁰ A. La Rosa,⁴⁹ J. L. La Rosa Navarro,^{24d} L. La Rotonda,^{37a,37b} C. Lacasta,¹⁶⁸ F. Lacava,^{133a,133b} J. Lacey,²⁹ H. Lacker,¹⁶ D. Lacour,⁸⁰ V. R. Lacuesta,¹⁶⁸ E. Ladygin,⁶⁵ R. Lafaye,⁵ B. Laforge,⁸⁰ T. Lagouri,¹⁷⁷ S. Lai,⁴⁸ L. Lambourne,⁷⁸ S. Lammers,⁶¹ C. L. Lampen,⁷ W. Lampl,⁷ E. Lançon,¹³⁷ U. Landgraf,⁴⁸ M. P. J. Landon,⁷⁶ V. S. Lang,^{58a} A. J. Lankford,¹⁶⁴ F. Lanni,²⁵ K. Lantzsch,³⁰ S. Laplace,⁸⁰ C. Lapoire,³⁰ J. F. Laporte,¹³⁷ T. Lari,^{91a} F. Lasagni Manghi,^{20a,20b} M. Lassnig,³⁰ P. Laurelli,⁴⁷ W. Lavrijsen,¹⁵ A. T. Law,¹³⁸ P. Laycock,⁷⁴ O. Le Dortz,⁸⁰ E. Le Guirrec,⁸⁵ E. Le Menedeu,¹² T. LeCompte,⁶ F. Ledroit-Guillon,⁵⁵ C. A. Lee,^{146b} S. C. Lee,¹⁵² L. Lee,¹ G. Lefebvre,⁸⁰ M. Lefebvre,¹⁷⁰ F. Legger,¹⁰⁰ C. Leggett,¹⁵ A. Lehan,⁷⁴ G. Lehmann Miotto,³⁰ X. Lei,⁷ W. A. Leight,²⁹ A. Leisos,¹⁵⁵ A. G. Leister,¹⁷⁷ M. A. L. Leite,^{24d} R. Leitner,¹²⁹ D. Lellouch,¹⁷³ B. Lemmer,⁵⁴ K. J. C. Leney,⁷⁸ T. Lenz,²¹ G. Lenzen,¹⁷⁶ B. Lenzi,³⁰ R. Leone,⁷ S. Leone,^{124a,124b} C. Leonidopoulos,⁴⁶ S. Leontsinis,¹⁰ C. Leroy,⁹⁵ C. G. Lester,²⁸ M. Levchenko,¹²³ J. Levêque,⁵ D. Levin,⁸⁹ L. J. Levinson,¹⁷³ M. Levy,¹⁸ A. Lewis,¹²⁰ A. M. Leyko,²¹ M. Leyton,⁴¹ B. Li,^{33b,w} B. Li,⁸⁵ H. Li,¹⁴⁹ H. L. Li,³¹ L. Li,⁴⁵ L. Li,^{33e} S. Li,⁴⁵ Y. Li,^{33c,x} Z. Liang,¹³⁸ H. Liao,³⁴ B. Liberti,^{134a} A. Liblong,¹⁵⁹ P. Lichard,³⁰ K. Lie,¹⁶⁶ J. Liebal,²¹ W. Liebig,¹⁴ C. Limbach,²¹ A. Limosani,¹⁵¹ S. C. Lin,^{152,y} T. H. Lin,⁸³ F. Linde,¹⁰⁷ B. E. Lindquist,¹⁴⁹ J. T. Linnemann,⁹⁰ E. Lipeles,¹²² A. Lipniacka,¹⁴ M. Lisovyi,⁴² T. M. Liss,¹⁶⁶ D. Lissauer,²⁵ A. Lister,¹⁶⁹ A. M. Litke,¹³⁸ B. Liu,¹⁵² D. Liu,¹⁵² J. Liu,⁸⁵ J. B. Liu,^{33b} K. Liu,^{33b,z} L. Liu,⁸⁹ M. Liu,⁴⁵ M. Liu,^{33b} Y. Liu,^{33b} M. Livan,^{121a,121b} A. Lleres,⁵⁵ J. Llorente Merino,⁸² S. L. Lloyd,⁷⁶ F. Lo Sterzo,¹⁵² E. Lobodzinska,⁴² P. Loch,⁷ W. S. Lockman,¹³⁸ F. K. Loebinger,⁸⁴ A. E. Loevschall-Jensen,³⁶ A. Loginov,¹⁷⁷ T. Lohse,¹⁶ K. Lohwasser,⁴² M. Lokajicek,¹²⁷ B. A. Long,²² J. D. Long,⁸⁹ R. E. Long,⁷² K. A. Looper,¹¹¹ L. Lopes,^{126a} D. Lopez Mateos,⁵⁷ B. Lopez Paredes,¹⁴⁰ I. Lopez Paz,¹² J. Lorenz,¹⁰⁰ N. Lorenzo Martinez,⁶¹ M. Losada,¹⁶³ P. Loscutoff,¹⁵ P. J. Lösel,¹⁰⁰ X. Lou,^{33a} A. Lounis,¹¹⁷ J. Love,⁶ P. A. Love,⁷² N. Lu,⁸⁹ H. J. Lubatti,¹³⁹ C. Luci,^{133a,133b} A. Lucotte,⁵⁵ F. Luehring,⁶¹ W. Lukas,⁶² L. Luminari,^{133a} O. Lundberg,^{147a,147b} B. Lund-Jensen,¹⁴⁸ M. Lungwitz,⁸³ D. Lynn,²⁵ R. Lysak,¹²⁷ E. Lytken,⁸¹ H. Ma,²⁵ L. L. Ma,^{33d} G. Maccarrone,⁴⁷ A. Macchiolo,¹⁰¹ C. M. Macdonald,¹⁴⁰ J. Machado Miguens,^{122,126b} D. Macina,³⁰ D. Madaffari,⁸⁵ R. Madar,³⁴ H. J. Maddocks,⁷² W. F. Mader,⁴⁴ A. Madsen,¹⁶⁷ S. Maeland,¹⁴ T. Maeno,²⁵ A. Maevskiy,⁹⁹ E. Magradze,⁵⁴ K. Mahboubi,⁴⁸ J. Mahlstedt,¹⁰⁷ S. Mahmoud,⁷⁴ C. Maiani,¹³⁷ C. Maidantchik,^{24a} A. A. Maier,¹⁰¹ T. Maier,¹⁰⁰ A. Maio,^{126a,126b,126d} S. Majewski,¹¹⁶ Y. Makida,⁶⁶ N. Makovec,¹¹⁷ B. Malaescu,⁸⁰ Pa. Malecki,³⁹ V. P. Maleev,¹²³ F. Malek,⁵⁵ U. Mallik,⁶³ D. Malon,⁶ C. Malone,¹⁴⁴ S. Maltezos,¹⁰ V. M. Malyshev,¹⁰⁹ S. Malyukov,³⁰ J. Mamuzic,⁴² G. Mancini,⁴⁷ B. Mandelli,³⁰ L. Mandelli,^{91a} I. Mandić,⁷⁵ R. Mandrysch,⁶³ J. Maneira,^{126a,126b} A. Manfredini,¹⁰¹ L. Manhaes de Andrade Filho,^{24b} J. Manjarres Ramos,^{160b} A. Mann,¹⁰⁰ P. M. Manning,¹³⁸ A. Manousakis-Katsikakis,⁹ B. Mansoulie,¹³⁷ R. Mantifel,⁸⁷ M. Mantoani,⁵⁴ L. Mapelli,³⁰ L. March,^{146c} G. Marchiori,⁸⁰ M. Marcisovsky,¹²⁷ C. P. Marino,¹⁷⁰ M. Marjanovic,¹³ F. Marroquim,^{24a} S. P. Marsden,⁸⁴ Z. Marshall,¹⁵ L. F. Marti,¹⁷ S. Marti-Garcia,¹⁶⁸ B. Martin,⁹⁰ T. A. Martin,¹⁷¹ V. J. Martin,⁴⁶ B. Martin dit Latour,¹⁴ H. Martinez,¹³⁷ M. Martinez,^{12,o} S. Martin-Haugh,¹³¹ V. S. Martoiu,^{26a} A. C. Martyniuk,⁷⁸ M. Marx,¹³⁹ F. Marzano,^{133a} A. Marzin,³⁰ L. Masetti,⁸³ T. Mashimo,¹⁵⁶ R. Mashinistov,⁹⁶ J. Masik,⁸⁴ A. L. Maslennikov,^{109,d} I. Massa,^{20a,20b} L. Massa,^{20a,20b} N. Massol,⁵ P. Mastrandrea,¹⁴⁹ A. Mastroberardino,^{37a,37b} T. Masubuchi,¹⁵⁶ P. Mättig,¹⁷⁶ J. Mattmann,⁸³ J. Maurer,^{26a} S. J. Maxfield,⁷⁴ D. A. Maximov,^{109,d} R. Mazini,¹⁵² S. M. Mazza,^{91a,91b} L. Mazzaferro,^{134a,134b} G. Mc Goldrick,¹⁵⁹ S. P. Mc Kee,⁸⁹ A. McCann,⁸⁹ R. L. McCarthy,¹⁴⁹ T. G. McCarthy,²⁹ N. A. McCubbin,¹³¹ K. W. McFarlane,^{56,a} J. A. Mcfayden,⁷⁸ G. Mchedlidze,⁵⁴ S. J. McMahon,¹³¹ R. A. McPherson,^{170,k} M. Medinnis,⁴² S. Meehan,^{146a} S. Mehlhase,¹⁰⁰ A. Mehta,⁷⁴ K. Meier,^{58a} C. Meineck,¹⁰⁰ B. Meirose,⁴¹ C. Melachrinou,³¹ B. R. Mellado Garcia,^{146c} F. Meloni,¹⁷ A. Mengarelli,^{20a,20b} S. Menke,¹⁰¹ E. Meoni,¹⁶² K. M. Mercurio,⁵⁷ S. Mergelmeyer,²¹ N. Meric,¹³⁷ P. Mermod,⁴⁹ L. Merola,^{104a,104b} C. Meroni,^{91a} F. S. Merritt,³¹ H. Merritt,¹¹¹ A. Messina,^{133a,133b} J. Metcalfe,²⁵ A. S. Mete,¹⁶⁴ C. Meyer,⁸³ C. Meyer,¹²² J.-P. Meyer,¹³⁷ J. Meyer,¹⁰⁷ R. P. Middleton,¹³¹ S. Miglioranza,^{165a,165c} L. Mijović,²¹ G. Mikenberg,¹⁷³ M. Mikestikova,¹²⁷ M. Mikuž,⁷⁵ M. Milesi,⁸⁸ A. Milic,³⁰ D. W. Miller,³¹ C. Mills,⁴⁶ A. Milov,¹⁷³ D. A. Milstead,^{147a,147b} A. A. Minaenko,¹³⁰ Y. Minami,¹⁵⁶ I. A. Minashvili,⁶⁵ A. I. Mincer,¹¹⁰ B. Mindur,^{38a} M. Mineev,⁶⁵ Y. Ming,¹⁷⁴ L. M. Mir,¹² G. Mirabelli,^{133a} T. Mitani,¹⁷² J. Mitrevski,¹⁰⁰ V. A. Mitsou,¹⁶⁸ A. Miucci,⁴⁹ P. S. Miyagawa,¹⁴⁰ J. U. Mjörnmark,⁸¹ T. Moa,^{147a,147b} K. Mochizuki,⁸⁵

- S. Mohapatra,³⁵ W. Mohr,⁴⁸ S. Molander,^{147a,147b} R. Moles-Valls,¹⁶⁸ K. Mönig,⁴² C. Monini,⁵⁵ J. Monk,³⁶ E. Monnier,⁸⁵
 J. Montejo Berlingen,¹² F. Monticelli,⁷¹ S. Monzani,^{133a,133b} R. W. Moore,³ N. Morange,¹¹⁷ D. Moreno,¹⁶³
 M. Moreno Llácer,⁵⁴ P. Morettini,^{50a} M. Morgenstern,⁴⁴ M. Morii,⁵⁷ V. Morisbak,¹¹⁹ S. Moritz,⁸³ A. K. Morley,¹⁴⁸
 G. Mornacchi,³⁰ J. D. Morris,⁷⁶ A. Morton,⁵³ L. Morvaj,¹⁰³ H. G. Moser,¹⁰¹ M. Mosidze,^{51b} J. Moss,¹¹¹ K. Motohashi,¹⁵⁸
 R. Mount,¹⁴⁴ E. Mountricha,²⁵ S. V. Mouraviev,^{96a} E. J. W. Moyse,⁸⁶ S. Muanza,⁸⁵ R. D. Mudd,¹⁸ F. Mueller,¹⁰¹
 J. Mueller,¹²⁵ K. Mueller,²¹ R. S. P. Mueller,¹⁰⁰ T. Mueller,²⁸ D. Muenstermann,⁴⁹ P. Mullen,⁵³ Y. Munwes,¹⁵⁴
 J. A. Murillo Quijada,¹⁸ W. J. Murray,^{171,131} H. Musheghyan,⁵⁴ E. Musto,¹⁵³ A. G. Myagkov,^{130aa} M. Myska,¹²⁸
 O. Nackenhorst,⁵⁴ J. Nadal,⁵⁴ K. Nagai,¹²⁰ R. Nagai,¹⁵⁸ Y. Nagai,⁸⁵ K. Nagano,⁶⁶ A. Nagarkar,¹¹¹ Y. Nagasaka,⁵⁹
 K. Nagata,¹⁶¹ M. Nagel,¹⁰¹ E. Nagy,⁸⁵ A. M. Nairz,³⁰ Y. Nakahama,³⁰ K. Nakamura,⁶⁶ T. Nakamura,¹⁵⁶ I. Nakano,¹¹²
 H. Namasivayam,⁴¹ G. Nanava,²¹ R. F. Naranjo Garcia,⁴² R. Narayan,^{58b} T. Nattermann,²¹ T. Naumann,⁴² G. Navarro,¹⁶³
 R. Nayyar,⁷ H. A. Neal,⁸⁹ P. Yu. Nechaeva,⁹⁶ T. J. Neep,⁸⁴ P. D. Nef,¹⁴⁴ A. Negri,^{121a,121b} M. Negrini,^{20a} S. Nektarijevic,¹⁰⁶
 C. Nellist,¹¹⁷ A. Nelson,¹⁶⁴ S. Nemecek,¹²⁷ P. Nemethy,¹¹⁰ A. A. Nepomuceno,^{24a} M. Nessi,^{30bb} M. S. Neubauer,¹⁶⁶
 M. Neumann,¹⁷⁶ R. M. Neves,¹¹⁰ P. Nevski,²⁵ P. R. Newman,¹⁸ D. H. Nguyen,⁶ R. B. Nickerson,¹²⁰ R. Nicolaidou,¹³⁷
 B. Nicquevert,³⁰ J. Nielsen,¹³⁸ N. Nikiforou,³⁵ A. Nikiforov,¹⁶ V. Nikolaenko,^{130aa} I. Nikolic-Audit,⁸⁰ K. Nikolopoulos,¹⁸
 J. K. Nilsen,¹¹⁹ P. Nilsson,²⁵ Y. Ninomiya,¹⁵⁶ A. Nisati,^{133a} R. Nisius,¹⁰¹ T. Nobe,¹⁵⁸ M. Nomachi,¹¹⁸ I. Nomidis,²⁹
 T. Nooney,⁷⁶ S. Norberg,¹¹³ M. Nordberg,³⁰ O. Novgorodova,⁴⁴ S. Nowak,¹⁰¹ M. Nozaki,⁶⁶ L. Nozka,¹¹⁵ K. Ntekas,¹⁰
 G. Nunes Hanninger,⁸⁸ T. Nunnemann,¹⁰⁰ E. Nurse,⁷⁸ F. Nuti,⁸⁸ B. J. O'Brien,⁴⁶ F. O'grady,⁷ D. C. O'Neil,¹⁴³ V. O'Shea,⁵³
 F. G. Oakham,^{29e} H. Oberlack,¹⁰¹ T. Obermann,²¹ J. Ocariz,⁸⁰ A. Ochi,⁶⁷ I. Ochoa,⁷⁸ S. Oda,⁷⁰ S. Odaka,⁶⁶ H. Ogren,⁶¹
 A. Oh,⁸⁴ S. H. Oh,⁴⁵ C. C. Ohm,¹⁵ H. Ohman,¹⁶⁷ H. Oide,³⁰ W. Okamura,¹¹⁸ H. Okawa,¹⁶¹ Y. Okumura,³¹ T. Okuyama,¹⁵⁶
 A. Olariu,^{26a} S. A. Olivares Pino,⁴⁶ D. Oliveira Damazio,²⁵ E. Oliver Garcia,¹⁶⁸ A. Olszewski,³⁹ J. Olszowska,³⁹
 A. Onofre,^{126a,126e} P. U. E. Onyisi,^{31q} C. J. Oram,^{160a} M. J. Oreglia,³¹ Y. Oren,¹⁵⁴ D. Orestano,^{135a,135b} N. Orlando,¹⁵⁵
 C. Oropeza Barrera,⁵³ R. S. Orr,¹⁵⁹ B. Osculati,^{50a,50b} R. Ospanov,⁸⁴ G. Otero y Garzon,²⁷ H. Otono,⁷⁰ M. Ouchrif,^{136d}
 E. A. Ouellette,¹⁷⁰ F. Ould-Saada,¹¹⁹ A. Ouraou,¹³⁷ K. P. Oussoren,¹⁰⁷ Q. Ouyang,^{33a} A. Ovcharova,¹⁵ M. Owen,⁵³
 R. E. Owen,¹⁸ V. E. Ozcan,^{19a} N. Ozturk,⁸ K. Pachal,¹²⁰ A. Pacheco Pages,¹² C. Padilla Aranda,¹² M. Pagáčová,⁴⁸
 S. Pagan Griso,¹⁵ E. Paganis,¹⁴⁰ C. Pahl,¹⁰¹ F. Paige,²⁵ P. Pais,⁸⁶ K. Pajchel,¹¹⁹ G. Palacino,^{160b} S. Palestini,³⁰ M. Palka,^{38b}
 D. Pallin,³⁴ A. Palma,^{126a,126b} Y. B. Pan,¹⁷⁴ E. Panagiotopoulou,¹⁰ C. E. Pandini,⁸⁰ J. G. Panduro Vazquez,⁷⁷ P. Pani,^{147a,147b}
 S. Panitkin,²⁵ L. Paolozzi,^{134a,134b} Th. D. Papadopolou,¹⁰ K. Papageorgiou,¹⁵⁵ A. Paramonov,⁶ D. Paredes Hernandez,¹⁵⁵
 M. A. Parker,²⁸ K. A. Parker,¹⁴⁰ F. Parodi,^{50a,50b} J. A. Parsons,³⁵ U. Parzefall,⁴⁸ E. Pasqualucci,^{133a} S. Passaggio,^{50a}
 F. Pastore,^{135a,135b,a} Fr. Pastore,⁷⁷ G. Pásztor,²⁹ S. Patariaia,¹⁷⁶ N. D. Patel,¹⁵¹ J. R. Pater,⁸⁴ T. Pauly,³⁰ J. Pearce,¹⁷⁰
 B. Pearson,¹¹³ L. E. Pedersen,³⁶ M. Pedersen,¹¹⁹ S. Pedraza Lopez,¹⁶⁸ R. Pedro,^{126a,126b} S. V. Peleganchuk,¹⁰⁹ D. Pelikan,¹⁶⁷
 H. Peng,^{33b} B. Penning,³¹ J. Penwell,⁶¹ D. V. Perepelitsa,²⁵ E. Perez Codina,^{160a} M. T. Pérez García-Estañ,¹⁶⁸ L. Perini,^{91a,91b}
 H. Pernegger,³⁰ S. Perrella,^{104a,104b} R. Peschke,⁴² V. D. Peshekhonov,⁶⁵ K. Peters,³⁰ R. F. Y. Peters,⁸⁴ B. A. Petersen,³⁰
 T. C. Petersen,³⁶ E. Petit,⁴² A. Petridis,^{147a,147b} C. Petridou,¹⁵⁵ E. Petrolo,^{133a} F. Petrucci,^{135a,135b} N. E. Pettersson,¹⁵⁸
 R. Pezoa,^{32b} P. W. Phillips,¹³¹ G. Piacquadio,¹⁴⁴ E. Pianori,¹⁷¹ A. Picazio,⁴⁹ E. Piccaro,⁷⁶ M. Piccinini,^{20a,20b}
 M. A. Pickering,¹²⁰ R. Piegaia,²⁷ D. T. Pignotti,¹¹¹ J. E. Pilcher,³¹ A. D. Pilkington,⁷⁸ J. Pina,^{126a,126b,126d}
 M. Pinamonti,^{165a,165c,cc} J. L. Pinfold,³ A. Pingel,³⁶ B. Pinto,^{126a} S. Pires,⁸⁰ M. Pitt,¹⁷³ C. Pizio,^{91a,91b} L. Plazak,^{145a}
 M.-A. Pleier,²⁵ V. Pleskot,¹²⁹ E. Plotnikova,⁶⁵ P. Plucinski,^{147a,147b} D. Pluth,⁶⁴ R. Poettgen,⁸³ L. Poggioli,¹¹⁷ D. Pohl,²¹
 G. Polesello,^{121a} A. Policicchio,^{37a,37b} R. Polifka,¹⁵⁹ A. Polini,^{20a} C. S. Pollard,⁵³ V. Polychronakos,²⁵ K. Pommès,³⁰
 L. Pontecorvo,^{133a} B. G. Pope,⁹⁰ G. A. Popeneciu,^{26b} D. S. Popovic,¹³ A. Poppleton,³⁰ S. Pospisil,¹²⁸ K. Potamianos,¹⁵
 I. N. Potrap,⁶⁵ C. J. Potter,¹⁵⁰ C. T. Potter,¹¹⁶ G. Poulard,³⁰ J. Poveda,³⁰ V. Pozdnyakov,⁶⁵ P. Pralavorio,⁸⁵ A. Pranko,¹⁵
 S. Prasad,³⁰ S. Prell,⁶⁴ D. Price,⁸⁴ J. Price,⁷⁴ L. E. Price,⁶ M. Primavera,^{73a} S. Prince,⁸⁷ M. Proissl,⁴⁶ K. Prokofiev,^{60c}
 F. Prokoshin,^{32b} E. Protopapadaki,¹³⁷ S. Protopopescu,²⁵ J. Proudfoot,⁶ M. Przybycien,^{38a} E. Ptacek,¹¹⁶ D. Puddu,^{135a,135b}
 E. Pueschel,⁸⁶ D. Puldon,¹⁴⁹ M. Purohit,^{25,dd} P. Puzo,¹¹⁷ J. Qian,⁸⁹ G. Qin,⁵³ Y. Qin,⁸⁴ A. Quadt,⁵⁴ D. R. Quarrie,¹⁵
 W. B. Quayle,^{165a,165b} M. Queitsch-Maitland,⁸⁴ D. Quilty,⁵³ A. Qureshi,^{160b} V. Radeka,²⁵ V. Radescu,⁴²
 S. K. Radhakrishnan,¹⁴⁹ P. Radloff,¹¹⁶ P. Rados,⁸⁸ F. Ragusa,^{91a,91b} G. Rahal,¹⁷⁹ S. Rajagopalan,²⁵ M. Rammensee,³⁰
 C. Rangel-Smith,¹⁶⁷ F. Rauscher,¹⁰⁰ S. Rave,⁸³ T. C. Rave,⁴⁸ T. Ravenscroft,⁵³ M. Raymond,³⁰ A. L. Read,¹¹⁹
 N. P. Radioff,⁷⁴ D. M. Rebuzzi,^{121a,121b} A. Redelbach,¹⁷⁵ G. Redlinger,²⁵ R. Reece,¹³⁸ K. Reeves,⁴¹ L. Rehnisch,¹⁶
 H. Reisin,²⁷ M. Relich,¹⁶⁴ C. Rembser,³⁰ H. Ren,^{33a} A. Renaud,¹¹⁷ M. Rescigno,^{133a} S. Resconi,^{91a} O. L. Rezanova,^{109,d}
 P. Reznicek,¹²⁹ R. Rezvani,⁹⁵ R. Richter,¹⁰¹ E. Richter-Was,^{38b} M. Ridel,⁸⁰ P. Rieck,¹⁶ C. J. Riegel,¹⁷⁶ J. Rieger,⁵⁴

- M. Rijssenbeek,¹⁴⁹ A. Rimoldi,^{121a,121b} L. Rinaldi,^{20a} E. Ritsch,⁶² I. Riu,¹² F. Rizatdinova,¹¹⁴ E. Rizvi,⁷⁶ S. H. Robertson,^{87,k}
A. Robichaud-Veronneau,⁸⁷ D. Robinson,²⁸ J. E. M. Robinson,⁸⁴ A. Robson,⁵³ C. Roda,^{124a,124b} L. Rodrigues,³⁰ S. Roe,³⁰
O. Røhne,¹¹⁹ S. Rolli,¹⁶² A. Romaniouk,⁹⁸ M. Romano,^{20a,20b} S. M. Romano Saez,³⁴ E. Romero Adam,¹⁶⁸ N. Rompotis,¹³⁹
M. Ronzani,⁴⁸ L. Roos,⁸⁰ E. Ros,¹⁶⁸ S. Rosati,^{133a} K. Rosbach,⁴⁸ P. Rose,¹³⁸ P. L. Rosendahl,¹⁴ O. Rosenthal,¹⁴²
V. Rossetti,^{147a,147b} E. Rossi,^{104a,104b} L. P. Rossi,^{50a} R. Rosten,¹³⁹ M. Rotaru,^{26a} I. Roth,¹⁷³ J. Rothberg,¹³⁹ D. Rousseau,¹¹⁷
C. R. Royon,¹³⁷ A. Rozanov,⁸⁵ Y. Rozen,¹⁵³ X. Ruan,^{146c} F. Rubbo,¹⁴⁴ I. Rubinskiy,⁴² V. I. Rud,⁹⁹ C. Rudolph,⁴⁴
M. S. Rudolph,¹⁵⁹ F. Rühr,⁴⁸ A. Ruiz-Martinez,³⁰ Z. Rurikova,⁴⁸ N. A. Rusakovich,⁶⁵ A. Ruschke,¹⁰⁰ H. L. Russell,¹³⁹
J. P. Rutherford,⁷ N. Ruthmann,⁴⁸ Y. F. Ryabov,¹²³ M. Rybar,¹²⁹ G. Rybkin,¹¹⁷ N. C. Ryder,¹²⁰ A. F. Saavedra,¹⁵¹
G. Sabato,¹⁰⁷ S. Sacerdoti,²⁷ A. Saddique,³ H. F.-W. Sadrozinski,¹³⁸ R. Sadykov,⁶⁵ F. Safai Tehrani,^{133a} M. Saimpert,¹³⁷
H. Sakamoto,¹⁵⁶ Y. Sakurai,¹⁷² G. Salamanna,^{135a,135b} A. Salamon,^{134a} M. Saleem,¹¹³ D. Salek,¹⁰⁷ P. H. Sales De Bruin,¹³⁹
D. Saliagic,¹⁰¹ A. Salnikov,¹⁴⁴ J. Salt,¹⁶⁸ D. Salvatore,^{37a,37b} F. Salvatore,¹⁵⁰ A. Salvucci,¹⁰⁶ A. Salzburger,³⁰
D. Sampsonidis,¹⁵⁵ A. Sanchez,^{104a,104b} J. Sánchez,¹⁶⁸ V. Sanchez Martinez,¹⁶⁸ H. Sandaker,¹⁴ R. L. Sandbach,⁷⁶
H. G. Sander,⁸³ M. P. Sanders,¹⁰⁰ M. Sandhoff,¹⁷⁶ C. Sandoval,¹⁶³ R. Sandstroem,¹⁰¹ D. P. C. Sankey,¹³¹ A. Sansoni,⁴⁷
C. Santoni,³⁴ R. Santonico,^{134a,134b} H. Santos,^{126a} I. Santoyo Castillo,¹⁵⁰ K. Sapp,¹²⁵ A. Sapronov,⁶⁵ J. G. Saraiva,^{126a,126d}
B. Sarrazin,²¹ O. Sasaki,⁶⁶ Y. Sasaki,¹⁵⁶ K. Sato,¹⁶¹ G. Sauvage,^{5,a} E. Sauvan,⁵ G. Savage,⁷⁷ P. Savard,^{159,e} C. Sawyer,¹²⁰
L. Sawyer,^{79,n} J. Saxon,³¹ C. Sbarra,^{20a} A. Sbrizzi,^{20a,20b} T. Scanlon,⁷⁸ D. A. Scannicchio,¹⁶⁴ M. Scarcella,¹⁵¹
V. Scarfone,^{37a,37b} J. Schaarschmidt,¹⁷³ P. Schacht,¹⁰¹ D. Schaefer,³⁰ R. Schaefer,⁴² J. Schaeffer,⁸³ S. Schaepe,²¹
S. Schaezel,^{58b} U. Schäfer,⁸³ A. C. Schaffer,¹¹⁷ D. Schaile,¹⁰⁰ R. D. Schamberger,¹⁴⁹ V. Scharf,^{58a} V. A. Schegelsky,¹²³
D. Scheirich,¹²⁹ M. Schernau,¹⁶⁴ C. Schiavi,^{50a,50b} C. Schillo,⁴⁸ M. Schioppa,^{37a,37b} S. Schlenker,³⁰ E. Schmidt,⁴⁸
K. Schmieden,³⁰ C. Schmitt,⁸³ S. Schmitt,^{58b} S. Schmitt,⁴² B. Schneider,^{160a} Y. J. Schnellbach,⁷⁴ U. Schnoor,⁴⁴
L. Schoeffel,¹³⁷ A. Schoening,^{58b} B. D. Schoenrock,⁹⁰ E. Schopf,²¹ A. L. S. Schorlemmer,⁵⁴ M. Schott,⁸³ D. Schouten,^{160a}
J. Schovancova,⁸ S. Schramm,¹⁵⁹ M. Schreyer,¹⁷⁵ C. Schroeder,⁸³ N. Schuh,⁸³ M. J. Schultens,²¹ H.-C. Schultz-Coulon,^{58a}
H. Schulz,¹⁶ M. Schumacher,⁴⁸ B. A. Schumm,¹³⁸ Ph. Schune,¹³⁷ C. Schwanenberger,⁸⁴ A. Schwartzman,¹⁴⁴
T. A. Schwarz,⁸⁹ Ph. Schwegler,¹⁰¹ Ph. Schwemling,¹³⁷ R. Schwienhorst,⁹⁰ J. Schwindling,¹³⁷ T. Schwindt,²¹
M. Schwoerer,⁵ F. G. Sciaccia,¹⁷ E. Scifo,¹¹⁷ G. Sciolla,²³ F. Scuri,^{124a,124b} F. Scutti,²¹ J. Searcy,⁸⁹ G. Sedov,⁴² E. Sedykh,¹²³
P. Seema,²¹ S. C. Seidel,¹⁰⁵ A. Seiden,¹³⁸ F. Seifert,¹²⁸ J. M. Seixas,^{24a} G. Sekhniaidze,^{104a} S. J. Sekula,⁴⁰ K. E. Selbach,⁴⁶
D. M. Seliverstov,^{123,a} N. Semprini-Cesari,^{20a,20b} C. Serfon,³⁰ L. Serin,¹¹⁷ L. Serkin,⁵⁴ T. Serre,⁸⁵ R. Seuster,^{160a}
H. Severini,¹¹³ T. Sfiligoj,⁷⁵ F. Sforza,¹⁰¹ A. Sfyrila,³⁰ E. Shabalina,⁵⁴ M. Shamim,¹¹⁶ L. Y. Shan,^{33a} R. Shang,¹⁶⁶
J. T. Shank,²² M. Shapiro,¹⁵ P. B. Shatalov,⁹⁷ K. Shaw,^{165a,165b} A. Shcherbakova,^{147a,147b} C. Y. Shehu,¹⁵⁰ P. Sherwood,⁷⁸
L. Shi,^{152,ee} S. Shimizu,⁶⁷ C. O. Shimmin,¹⁶⁴ M. Shimojima,¹⁰² M. Shiyakova,⁶⁵ A. Shmeleva,⁹⁶ D. Shoaleh Saadi,⁹⁵
M. J. Shochet,³¹ S. Shojaii,^{91a,91b} S. Shrestha,¹¹¹ E. Shulga,⁹⁸ M. A. Shupe,⁷ S. Shushkevich,⁴² P. Sicho,¹²⁷
O. Sidiropoulou,¹⁷⁵ D. Sidorov,¹¹⁴ A. Sidoti,^{20a,20b} F. Siegert,⁴⁴ Dj. Sijacki,¹³ J. Silva,^{126a,126d} Y. Silver,¹⁵⁴ D. Silverstein,¹⁴⁴
S. B. Silverstein,^{147a} V. Simak,¹²⁸ O. Simard,⁵ Lj. Simic,¹³ S. Simion,¹¹⁷ E. Simioni,⁸³ B. Simmons,⁷⁸ D. Simon,³⁴
R. Simoniello,^{91a,91b} P. Sinervo,¹⁵⁹ N. B. Sinev,¹¹⁶ G. Siragusa,¹⁷⁵ A. N. Sisakyan,^{65,a} S. Yu. Sivoklov,⁹⁹ J. Sjölin,^{147a,147b}
T. B. Sjaursen,¹⁴ M. B. Skinner,⁷² H. P. Skottowe,⁵⁷ P. Skubic,¹¹³ M. Slater,¹⁸ T. Slavicek,¹²⁸ M. Slawinska,¹⁰⁷ K. Sliwa,¹⁶²
V. Smakhtin,¹⁷³ B. H. Smart,⁴⁶ L. Smestad,¹⁴ S. Yu. Smirnov,⁹⁸ Y. Smirnov,⁹⁸ L. N. Smirnova,^{99,ff} O. Smirnova,⁸¹
M. N. K. Smith,³⁵ M. Smizanska,⁷² K. Smolek,¹²⁸ A. A. Snesarev,⁹⁶ G. Snidero,⁷⁶ S. Snyder,²⁵ R. Sobie,^{170,k} F. Socher,⁴⁴
A. Soffer,¹⁵⁴ D. A. Soh,^{152,ee} C. A. Solans,³⁰ M. Solar,¹²⁸ J. Solc,¹²⁸ E. Yu. Soldatov,⁹⁸ U. Soldevila,¹⁶⁸ A. A. Solodkov,¹³⁰
A. Soloshenko,⁶⁵ O. V. Solovyanov,¹³⁰ V. Solovyev,¹²³ P. Sommer,⁴⁸ H. Y. Song,^{33b} N. Soni,¹ A. Sood,¹⁵ A. Sopczak,¹²⁸
B. Sopko,¹²⁸ V. Sopko,¹²⁸ V. Sorin,¹² D. Sosa,^{58b} M. Sosebee,⁸ C. L. Sotiropoulou,¹⁵⁵ R. Soualah,^{165a,165c} P. Soueid,⁹⁵
A. M. Soukharev,^{109,d} D. South,⁴² S. Spagnolo,^{73a,73b} F. Spanò,⁷⁷ W. R. Spearman,⁵⁷ F. Spettel,¹⁰¹ R. Spighi,^{20a} G. Spigo,³⁰
L. A. Spiller,⁸⁸ M. Spousta,¹²⁹ T. Spreitzer,¹⁵⁹ R. D. St. Denis,^{53,a} S. Staerz,⁴⁴ J. Stahlman,¹²² R. Stamen,^{58a} S. Stamm,¹⁶
E. Stanecka,³⁹ C. Stancu,^{135a} M. Stancu-Bellu,⁴² M. M. Stanitzki,⁴² S. Stapnes,¹¹⁹ E. A. Starchenko,¹³⁰ J. Stark,⁵⁵
P. Staroba,¹²⁷ P. Starovoitov,⁴² R. Staszewski,³⁹ P. Stavina,^{145a,a} P. Steinberg,²⁵ B. Stelzer,¹⁴³ H. J. Stelzer,³⁰
O. Stelzer-Chilton,^{160a} H. Stenzel,⁵² S. Stern,¹⁰¹ G. A. Stewart,⁵³ J. A. Stillings,²¹ M. C. Stockton,⁸⁷ M. Stoebe,⁸⁷
G. Stoicea,^{26a} P. Stolte,⁵⁴ S. Stonjek,¹⁰¹ A. R. Stradling,⁸ A. Straessner,⁴⁴ M. E. Stramaglia,¹⁷ J. Strandberg,¹⁴⁸
S. Strandberg,^{147a,147b} A. Strandlie,¹¹⁹ E. Strauss,¹⁴⁴ M. Strauss,¹¹³ P. Strizenec,^{145b} R. Ströhmer,¹⁷⁵ D. M. Strom,¹¹⁶
R. Stroynowski,⁴⁰ A. Strubig,¹⁰⁶ S. A. Stucci,¹⁷ B. Stugu,¹⁴ N. A. Styles,⁴² D. Su,¹⁴⁴ J. Su,¹²⁵ R. Subramaniam,⁷⁹
A. Succurro,¹² Y. Sugaya,¹¹⁸ C. Suhr,¹⁰⁸ M. Suk,¹²⁸ V. V. Sulin,⁹⁶ S. Sultansoy,^{4d} T. Sumida,⁶⁸ S. Sun,⁵⁷ X. Sun,^{33a}

- J. E. Sundermann,⁴⁸ K. Suruliz,¹⁵⁰ G. Susinno,^{37a,37b} M. R. Sutton,¹⁵⁰ Y. Suzuki,⁶⁶ M. Svatos,¹²⁷ S. Swedish,¹⁶⁹ M. Swiatlowski,¹⁴⁴ I. Sykora,^{145a} T. Sykora,¹²⁹ D. Ta,⁹⁰ C. Taccini,^{135a,135b} K. Tackmann,⁴² J. Taenzer,¹⁵⁹ A. Taffard,¹⁶⁴ R. Tafirout,^{160a} N. Taiblum,¹⁵⁴ H. Takai,²⁵ R. Takashima,⁶⁹ H. Takeda,⁶⁷ T. Takeshita,¹⁴¹ Y. Takubo,⁶⁶ M. Talby,⁸⁵ A. A. Talyshev,^{109,d} J. Y. C. Tam,¹⁷⁵ K. G. Tan,⁸⁸ J. Tanaka,¹⁵⁶ R. Tanaka,¹¹⁷ S. Tanaka,¹³² S. Tanaka,⁶⁶ A. J. Tanasijczuk,¹⁴³ B. B. Tannenwald,¹¹¹ N. Tannoury,²¹ S. Tapprogge,⁸³ S. Tarem,¹⁵³ F. Tarrade,²⁹ G. F. Tartarelli,^{91a} P. Tas,¹²⁹ M. Tasevsky,¹²⁷ T. Tashiro,⁶⁸ E. Tassi,^{37a,37b} A. Tavares Delgado,^{126a,126b} Y. Tayalati,^{136d} F. E. Taylor,⁹⁴ G. N. Taylor,⁸⁸ W. Taylor,^{160b} F. A. Teischinger,³⁰ M. Teixeira Dias Castanheira,⁷⁶ P. Teixeira-Dias,⁷⁷ K. K. Temming,⁴⁸ H. Ten Kate,³⁰ P. K. Teng,¹⁵² J. J. Teoh,¹¹⁸ F. Tepel,¹⁷⁶ S. Terada,⁶⁶ K. Terashi,¹⁵⁶ J. Terron,⁸² S. Terzo,¹⁰¹ M. Testa,⁴⁷ R. J. Teuscher,^{159,k} J. Therhaag,²¹ T. Theveniaux-Pelzer,³⁴ J. P. Thomas,¹⁸ J. Thomas-Wilsker,⁷⁷ E. N. Thompson,³⁵ P. D. Thompson,¹⁸ R. J. Thompson,⁸⁴ A. S. Thompson,⁵³ L. A. Thomsen,³⁶ E. Thomson,¹²² M. Thomson,²⁸ R. P. Thun,^{89,a} F. Tian,³⁵ M. J. Tibbetts,¹⁵ R. E. Ticse Torres,⁸⁵ V. O. Tikhomirov,^{96,gg} Yu. A. Tikhonov,^{109,d} S. Timoshenko,⁹⁸ E. Tiouchichine,⁸⁵ P. Tipton,¹⁷⁷ S. Tisserant,⁸⁵ T. Todorov,^{5,a} S. Todorova-Nova,¹²⁹ J. Tojo,⁷⁰ S. Tokár,^{145a} K. Tokushuku,⁶⁶ K. Tollefson,⁹⁰ E. Tolley,⁵⁷ L. Tomlinson,⁸⁴ M. Tomoto,¹⁰³ L. Tompkins,^{144,hh} K. Toms,¹⁰⁵ E. Torrence,¹¹⁶ H. Torres,¹⁴³ E. Torró Pastor,¹⁶⁸ J. Toth,^{85,ii} F. Touchard,⁸⁵ D. R. Tovey,¹⁴⁰ H. L. Tran,¹¹⁷ T. Trefzger,¹⁷⁵ L. Tremblet,³⁰ A. Tricoli,³⁰ I. M. Trigger,^{160a} S. Trincaz-Duvoid,⁸⁰ M. F. Tripiiana,¹² W. Trischuk,¹⁵⁹ B. Trocmé,⁵⁵ C. Troncon,^{91a} M. Trottier-McDonald,¹⁵ M. Trovatelli,^{135a,135b} P. True,⁹⁰ M. Trzebinski,³⁹ A. Trzupek,³⁹ C. Tsarouchas,³⁰ J. C-L. Tseng,¹²⁰ P. V. Tsiareshka,⁹² D. Tsionou,¹⁵⁵ G. Tsipolitis,¹⁰ N. Tsirintanis,⁹ S. Tsiskaridze,¹² V. Tsiskaridze,⁴⁸ E. G. Tskhadadze,^{51a} I. I. Tsukerman,⁹⁷ V. Tsulaia,¹⁵ S. Tsuno,⁶⁶ D. Tsybychev,¹⁴⁹ A. Tudorache,^{26a} V. Tudorache,^{26a} A. N. Tuna,¹²² S. A. Tuppiti,^{20a,20b} S. Turchikhin,^{99,ff} D. Turecek,¹²⁸ R. Turra,^{91a,91b} A. J. Turvey,⁴⁰ P. M. Tuts,³⁵ A. Tykhonov,⁴⁹ M. Tylmad,^{147a,147b} M. Tyndel,¹³¹ I. Ueda,¹⁵⁶ R. Ueno,²⁹ M. Ughetto,^{147a,147b} M. Ugland,¹⁴ M. Uhlenbrock,²¹ F. Ukegawa,¹⁶¹ G. Unal,³⁰ A. Undrus,²⁵ G. Unel,¹⁶⁴ F. C. Ungaro,⁴⁸ Y. Unno,⁶⁶ C. Unverdorben,¹⁰⁰ J. Urban,^{145b} P. Urquijo,⁸⁸ P. Urrejola,⁸³ G. Usai,⁸ A. Usanova,⁶² L. Vacavant,⁸⁵ V. Vacek,¹²⁸ B. Vachon,⁸⁷ N. Valencic,¹⁰⁷ S. Valentinetti,^{20a,20b} A. Valero,¹⁶⁸ L. Valery,¹² S. Valkar,¹²⁹ E. Valladolid Gallego,¹⁶⁸ S. Vallecorsa,⁴⁹ J. A. Valls Ferrer,¹⁶⁸ W. Van Den Wollenberg,¹⁰⁷ P. C. Van Der Deijl,¹⁰⁷ R. van der Geer,¹⁰⁷ H. van der Graaf,¹⁰⁷ R. Van Der Leeuw,¹⁰⁷ N. van Eldik,¹⁵³ P. van Gemmeren,⁶ J. Van Nieuwkoop,¹⁴³ I. van Vulpen,¹⁰⁷ M. C. van Woerden,³⁰ M. Vanadia,^{133a,133b} W. Vandelli,³⁰ R. Vanguri,¹²² A. Vaniachine,⁶ F. Vannucci,⁸⁰ G. Vardanyan,¹⁷⁸ R. Vari,^{133a} E. W. Varnes,⁷ T. Varol,⁴⁰ D. Varouchas,⁸⁰ A. Vartapetian,⁸ K. E. Varvell,¹⁵¹ F. Vazeille,³⁴ T. Vazquez Schroeder,⁵⁴ J. Veatch,⁷ F. Veloso,^{126a,126c} T. Velz,²¹ S. Veneziano,^{133a} A. Ventura,^{73a,73b} D. Ventura,⁸⁶ M. Venturi,¹⁷⁰ N. Venturi,¹⁵⁹ A. Venturini,²³ V. Vercesi,^{121a} M. Verducci,^{133a,133b} W. Verkerke,¹⁰⁷ J. C. Vermeulen,¹⁰⁷ A. Vest,⁴⁴ M. C. Vetterli,^{143,e} O. Viazlo,⁸¹ I. Vichou,¹⁶⁶ T. Vickey,^{146c,jj} O. E. Vickey Boeriu,^{146c} G. H. A. Viehhauser,¹²⁰ S. Viel,¹⁵ R. Vigne,³⁰ M. Villa,^{20a,20b} M. Villaplana Perez,^{91a,91b} E. Vilucchi,⁴⁷ M. G. Vincet,²⁹ V. B. Vinogradov,⁶⁵ I. Vivarelli,¹⁵⁰ F. Vives Vaque,³ S. Vlachos,¹⁰ D. Vladioiu,¹⁰⁰ M. Vlasak,¹²⁸ M. Vogel,^{32a} P. Vokac,¹²⁸ G. Volpi,^{124a,124b} M. Volpi,⁸⁸ H. von der Schmitt,¹⁰¹ H. von Radziewski,⁴⁸ E. von Toerne,²¹ V. Vorobel,¹²⁹ K. Vorobev,⁹⁸ M. Vos,¹⁶⁸ R. Voss,³⁰ J. H. Vosseveld,⁷⁴ N. Vranjes,¹³ M. Vranjes Milosavljevic,¹³ V. Vrba,¹²⁷ M. Vreeswijk,¹⁰⁷ R. Vuillermet,³⁰ I. Vukotic,³¹ Z. Vykydal,¹²⁸ P. Wagner,²¹ W. Wagner,¹⁷⁶ H. Wahlberg,⁷¹ S. Wahrmund,⁴⁴ J. Wakabayashi,¹⁰³ J. Walder,⁷² R. Walker,¹⁰⁰ W. Walkowiak,¹⁴² C. Wang,^{33c} F. Wang,¹⁷⁴ H. Wang,¹⁵ H. Wang,⁴⁰ J. Wang,⁴² J. Wang,^{33a} K. Wang,⁸⁷ R. Wang,⁶ S. M. Wang,¹⁵² T. Wang,²¹ X. Wang,¹⁷⁷ C. Wanotayaroj,¹¹⁶ A. Warburton,⁸⁷ C. P. Ward,²⁸ D. R. Wardrope,⁷⁸ M. Warsinsky,⁴⁸ A. Washbrook,⁴⁶ C. Wasicki,⁴² P. M. Watkins,¹⁸ A. T. Watson,¹⁸ I. J. Watson,¹⁵¹ M. F. Watson,¹⁸ G. Watts,¹³⁹ S. Watts,⁸⁴ B. M. Waugh,⁷⁸ S. Webb,⁸⁴ M. S. Weber,¹⁷ S. W. Weber,¹⁷⁵ J. S. Webster,³¹ A. R. Weidberg,¹²⁰ B. Weinert,⁶¹ J. Weingarten,⁵⁴ C. Weiser,⁴⁸ H. Weits,¹⁰⁷ P. S. Wells,³⁰ T. Wenaus,²⁵ D. Wendland,¹⁶ T. Wengler,³⁰ S. Wenig,³⁰ N. Wermes,²¹ M. Werner,⁴⁸ P. Werner,³⁰ M. Wessels,^{58a} J. Wetter,¹⁶² K. Whalen,²⁹ A. M. Wharton,⁷² A. White,⁸ M. J. White,¹ R. White,^{32b} S. White,^{124a,124b} D. Whiteson,¹⁶⁴ D. Wicke,¹⁷⁶ F. J. Wickens,¹³¹ W. Wiedenmann,¹⁷⁴ M. WIELERS,¹³¹ P. Wienemann,²¹ C. Wiglesworth,³⁶ L. A. M. Wiik-Fuchs,²¹ A. Wildauer,¹⁰¹ H. G. Wilkens,³⁰ H. H. Williams,¹²² S. Williams,¹⁰⁷ C. Willis,⁹⁰ S. Willocq,⁸⁶ A. Wilson,⁸⁹ J. A. Wilson,¹⁸ I. Wingerter-Seez,⁵ F. Winklmeier,¹¹⁶ B. T. Winter,²¹ M. Wittgen,¹⁴⁴ J. Wittkowski,¹⁰⁰ S. J. Wollstadt,⁸³ M. W. Wolter,³⁹ H. Wolters,^{126a,126c} B. K. Wosiek,³⁹ J. Wotschack,³⁰ M. J. Woudstra,⁸⁴ K. W. Wozniak,³⁹ M. Wu,⁵⁵ M. Wu,³¹ S. L. Wu,¹⁷⁴ X. Wu,⁴⁹ Y. Wu,⁸⁹ T. R. Wyatt,⁸⁴ B. M. Wynne,⁴⁶ S. Xella,³⁶ D. Xu,^{33a} L. Xu,^{33b,kk} B. Yabsley,¹⁵¹ S. Yacoub,^{146b,ll} R. Yakabe,⁶⁷ M. Yamada,⁶⁶ Y. Yamaguchi,¹¹⁸ A. Yamamoto,⁶⁶ S. Yamamoto,¹⁵⁶ T. Yamanaka,¹⁵⁶ K. Yamauchi,¹⁰³ Y. Yamazaki,⁶⁷ Z. Yan,²² H. Yang,^{33e} H. Yang,¹⁷⁴ Y. Yang,¹⁵² S. Yanush,⁹³ L. Yao,^{33a} W-M. Yao,¹⁵ Y. Yasu,⁶⁶ E. Yatsenko,⁴² K. H. Yau Wong,²¹ J. Ye,⁴⁰ S. Ye,²⁵ I. Yeletskikh,⁶⁵ A. L. Yen,⁵⁷ E. Yildirim,⁴²

K. Yorita,¹⁷² R. Yoshida,⁶ K. Yoshihara,¹²² C. Young,¹⁴⁴ C. J. S. Young,³⁰ S. Youssef,²² D. R. Yu,¹⁵ J. Yu,⁸ J. M. Yu,⁸⁹ J. Yu,¹¹⁴ L. Yuan,⁶⁷ A. Yurkewicz,¹⁰⁸ I. Yusuff,^{28,nmm} B. Zabinski,³⁹ R. Zaidan,⁶³ A. M. Zaitsev,^{130,aa} A. Zaman,¹⁴⁹ S. Zambito,²³ L. Zanello,^{133a,133b} D. Zanzi,⁸⁸ C. Zeitnitz,¹⁷⁶ M. Zeman,¹²⁸ A. Zemla,^{38a} K. Zengel,²³ O. Zenin,¹³⁰ T. Ženiš,^{145a} D. Zerwas,¹¹⁷ D. Zhang,⁸⁹ F. Zhang,¹⁷⁴ J. Zhang,⁶ L. Zhang,¹⁵² R. Zhang,^{33b} X. Zhang,^{33d} Z. Zhang,¹¹⁷ X. Zhao,⁴⁰ Y. Zhao,^{33d,117} Z. Zhao,^{33b} A. Zhemchugov,⁶⁵ J. Zhong,¹²⁰ B. Zhou,⁸⁹ C. Zhou,⁴⁵ L. Zhou,³⁵ L. Zhou,⁴⁰ N. Zhou,¹⁶⁴ C. G. Zhu,^{33d} H. Zhu,^{33a} J. Zhu,⁸⁹ Y. Zhu,^{33b} X. Zhuang,^{33a} K. Zhukov,⁹⁶ A. Zibell,¹⁷⁵ D. Zieminska,⁶¹ N. I. Zimine,⁶⁵ C. Zimmermann,⁸³ R. Zimmermann,²¹ S. Zimmermann,⁴⁸ Z. Zinonos,⁵⁴ M. Zinser,⁸³ M. Ziolkowski,¹⁴² L. Živković,¹³ G. Zobernig,¹⁷⁴ A. Zoccoli,^{20a,20b} M. zur Nedden,¹⁶ G. Zurzolo,^{104a,104b} and L. Zwalinski³⁰

(ATLAS Collaboration)

¹*Department of Physics, University of Adelaide, Adelaide, Australia*

²*Physics Department, SUNY Albany, Albany NY, USA*

³*Department of Physics, University of Alberta, Edmonton AB, Canada*

^{4a}*Department of Physics, Ankara University, Ankara, Turkey*

^{4b}*Istanbul Aydin University, Istanbul, Turkey*

^{4c}*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*

⁵*LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*

⁶*High Energy Physics Division, Argonne National Laboratory, Argonne IL, USA*

⁷*Department of Physics, University of Arizona, Tucson AZ, USA*

⁸*Department of Physics, The University of Texas at Arlington, Arlington TX, USA*

⁹*Physics Department, University of Athens, Athens, Greece*

¹⁰*Physics Department, National Technical University of Athens, Zografou, Greece*

¹¹*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*

¹²*Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain*

¹³*Institute of Physics, University of Belgrade, Belgrade, Serbia*

¹⁴*Department for Physics and Technology, University of Bergen, Bergen, Norway*

¹⁵*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley CA, USA*

¹⁶*Department of Physics, Humboldt University, Berlin, Germany*

¹⁷*Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland*

¹⁸*School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom*

^{19a}*Department of Physics, Bogazici University, Istanbul, Turkey*

^{19b}*Department of Physics, Dogus University, Istanbul, Turkey*

^{19c}*Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey*

^{20a}*INFN Sezione di Bologna, Italy*

^{20b}*Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*

²¹*Physikalisches Institut, University of Bonn, Bonn, Germany*

²²*Department of Physics, Boston University, Boston MA, USA*

²³*Department of Physics, Brandeis University, Waltham MA, USA*

^{24a}*Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil*

^{24b}*Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil*

^{24c}*Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil*

^{24d}*Instituto de Física, Universidade de Sao Paulo, Sao Paulo, Brazil*

²⁵*Physics Department, Brookhaven National Laboratory, Upton NY, USA*

^{26a}*National Institute of Physics and Nuclear Engineering, Bucharest, Romania*

^{26b}*National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania*

^{26c}*University Politehnica Bucharest, Bucharest, Romania*

^{26d}*West University in Timisoara, Timisoara, Romania*

²⁷*Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina*

²⁸*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*

²⁹*Department of Physics, Carleton University, Ottawa ON, Canada*

³⁰*CERN, Geneva, Switzerland*

³¹*Enrico Fermi Institute, University of Chicago, Chicago IL, USA*

^{32a}*Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile*

^{32b}*Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile*

^{33a}*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*

^{33b}*Department of Modern Physics, University of Science and Technology of China, Anhui, China*

- ^{33c}Department of Physics, Nanjing University, Jiangsu, China
^{33d}School of Physics, Shandong University, Shandong, China
^{33e}Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai, China
^{33f}Physics Department, Tsinghua University, Beijing 100084, China
³⁴Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
³⁵Nevis Laboratory, Columbia University, Irvington NY, USA
³⁶Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
^{37a}INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy
^{37b}Dipartimento di Fisica, Università della Calabria, Rende, Italy
^{38a}AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
^{38b}Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
³⁹Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
⁴⁰Physics Department, Southern Methodist University, Dallas TX, USA
⁴¹Physics Department, University of Texas at Dallas, Richardson TX, USA
⁴²DESY, Hamburg and Zeuthen, Germany
⁴³Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
⁴⁴Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
⁴⁵Department of Physics, Duke University, Durham NC, USA
⁴⁶SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
⁴⁷INFN Laboratori Nazionali di Frascati, Frascati, Italy
⁴⁸Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
⁴⁹Section de Physique, Université de Genève, Geneva, Switzerland
^{50a}INFN Sezione di Genova, Italy
^{50b}Dipartimento di Fisica, Università di Genova, Genova, Italy
^{51a}E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi, Georgia
^{51b}High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
⁵²II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
⁵³SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
⁵⁴II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
⁵⁵Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
⁵⁶Department of Physics, Hampton University, Hampton VA, USA
⁵⁷Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge MA, USA
^{58a}Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
^{58b}Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
^{58c}ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
⁵⁹Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
^{60a}Department of Physics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
^{60b}Department of Physics, The University of Hong Kong, Hong Kong, China
^{60c}Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
⁶¹Department of Physics, Indiana University, Bloomington IN, USA
⁶²Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
⁶³University of Iowa, Iowa City IA, USA
⁶⁴Department of Physics and Astronomy, Iowa State University, Ames IA, USA
⁶⁵Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
⁶⁶KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
⁶⁷Graduate School of Science, Kobe University, Kobe, Japan
⁶⁸Faculty of Science, Kyoto University, Kyoto, Japan
⁶⁹Kyoto University of Education, Kyoto, Japan
⁷⁰Department of Physics, Kyushu University, Fukuoka, Japan
⁷¹Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
⁷²Physics Department, Lancaster University, Lancaster, United Kingdom
^{73a}INFN Sezione di Lecce, Italy
^{73b}Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
⁷⁴Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom
⁷⁵Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
⁷⁶School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom
⁷⁷Department of Physics, Royal Holloway University of London, Surrey, United Kingdom
⁷⁸Department of Physics and Astronomy, University College London, London, United Kingdom

- ⁷⁹Louisiana Tech University, Ruston LA, USA
- ⁸⁰Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁸¹Fysiska institutionen, Lunds universitet, Lund, Sweden
- ⁸²Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- ⁸³Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸⁴School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom
- ⁸⁵CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁶Department of Physics, University of Massachusetts, Amherst MA, USA
- ⁸⁷Department of Physics, McGill University, Montreal QC, Canada
- ⁸⁸School of Physics, University of Melbourne, Victoria, Australia
- ⁸⁹Department of Physics, The University of Michigan, Ann Arbor MI, USA
- ⁹⁰Department of Physics and Astronomy, Michigan State University, East Lansing MI, USA
- ^{91a}INFN Sezione di Milano, Italy
- ^{91b}Dipartimento di Fisica, Università di Milano, Milano, Italy
- ⁹²B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- ⁹³National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- ⁹⁴Department of Physics, Massachusetts Institute of Technology, Cambridge MA, USA
- ⁹⁵Group of Particle Physics, University of Montreal, Montreal QC, Canada
- ⁹⁶P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- ⁹⁷Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- ⁹⁸National Research Nuclear University MEPhI, Moscow, Russia
- ⁹⁹D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- ¹⁰⁰Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany
- ¹⁰¹Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany
- ¹⁰²Nagasaki Institute of Applied Science, Nagasaki, Japan
- ¹⁰³Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- ^{104a}INFN Sezione di Napoli, Italy
- ^{104b}Dipartimento di Fisica, Università di Napoli, Napoli, Italy
- ¹⁰⁵Department of Physics and Astronomy, University of New Mexico, Albuquerque NM, USA
- ¹⁰⁶Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands
- ¹⁰⁷Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands
- ¹⁰⁸Department of Physics, Northern Illinois University, DeKalb IL, USA
- ¹⁰⁹Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- ¹¹⁰Department of Physics, New York University, New York NY, USA
- ¹¹¹Ohio State University, Columbus OH, USA
- ¹¹²Faculty of Science, Okayama University, Okayama, Japan
- ¹¹³Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman OK, USA
- ¹¹⁴Department of Physics, Oklahoma State University, Stillwater OK, USA
- ¹¹⁵Palacký University, RCPTM, Olomouc, Czech Republic
- ¹¹⁶Center for High Energy Physics, University of Oregon, Eugene OR, USA
- ¹¹⁷LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- ¹¹⁸Graduate School of Science, Osaka University, Osaka, Japan
- ¹¹⁹Department of Physics, University of Oslo, Oslo, Norway
- ¹²⁰Department of Physics, Oxford University, Oxford, United Kingdom
- ^{121a}INFN Sezione di Pavia, Italy
- ^{121b}Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- ¹²²Department of Physics, University of Pennsylvania, Philadelphia PA, USA
- ¹²³Petersburg Nuclear Physics Institute, Gatchina, Russia
- ^{124a}INFN Sezione di Pisa, Italy
- ^{124b}Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- ¹²⁵Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh PA, USA
- ^{126a}Laboratório de Instrumentação e Física Experimental de Partículas - LIP, Lisboa, Portugal
- ^{126b}Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal
- ^{126c}Department of Physics, University of Coimbra, Coimbra, Portugal
- ^{126d}Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal
- ^{126e}Departamento de Física, Universidade do Minho, Braga, Portugal
- ^{126f}Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain
- ^{126g}Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- ¹²⁷Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic
- ¹²⁸Czech Technical University in Prague, Praha, Czech Republic

- ¹²⁹*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
- ¹³⁰*State Research Center Institute for High Energy Physics, Protvino, Russia*
- ¹³¹*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
- ¹³²*Ritsumeikan University, Kusatsu, Shiga, Japan*
- ^{133a}*INFN Sezione di Roma, Italy*
- ^{133b}*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
- ^{134a}*INFN Sezione di Roma Tor Vergata, Italy*
- ^{134b}*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
- ^{135a}*INFN Sezione di Roma Tre, Italy*
- ^{135b}*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
- ^{136a}*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco*
- ^{136b}*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
- ^{136c}*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*
- ^{136d}*Faculté des Sciences, Université Mohamed Premier and LTPM, Oujda, Morocco*
- ^{136e}*Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco*
- ¹³⁷*DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France*
- ¹³⁸*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz CA, USA*
- ¹³⁹*Department of Physics, University of Washington, Seattle WA, USA*
- ¹⁴⁰*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
- ¹⁴¹*Department of Physics, Shinshu University, Nagano, Japan*
- ¹⁴²*Fachbereich Physik, Universität Siegen, Siegen, Germany*
- ¹⁴³*Department of Physics, Simon Fraser University, Burnaby BC, Canada*
- ¹⁴⁴*SLAC National Accelerator Laboratory, Stanford CA, USA*
- ^{145a}*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*
- ^{145b}*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
- ^{146a}*Department of Physics, University of Cape Town, Cape Town, South Africa*
- ^{146b}*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
- ^{146c}*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
- ^{147a}*Department of Physics, Stockholm University, Sweden*
- ^{147b}*The Oskar Klein Centre, Stockholm, Sweden*
- ¹⁴⁸*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
- ¹⁴⁹*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook NY, USA*
- ¹⁵⁰*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*
- ¹⁵¹*School of Physics, University of Sydney, Sydney, Australia*
- ¹⁵²*Institute of Physics, Academia Sinica, Taipei, Taiwan*
- ¹⁵³*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
- ¹⁵⁴*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
- ¹⁵⁵*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
- ¹⁵⁶*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
- ¹⁵⁷*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
- ¹⁵⁸*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
- ¹⁵⁹*Department of Physics, University of Toronto, Toronto ON, Canada*
- ^{160a}*TRIUMF, Vancouver BC, Canada*
- ^{160b}*Department of Physics and Astronomy, York University, Toronto ON, Canada*
- ¹⁶¹*Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan*
- ¹⁶²*Department of Physics and Astronomy, Tufts University, Medford MA, USA*
- ¹⁶³*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
- ¹⁶⁴*Department of Physics and Astronomy, University of California Irvine, Irvine CA, USA*
- ^{165a}*INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy*
- ^{165b}*ICTP, Trieste, Italy*
- ^{165c}*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*
- ¹⁶⁶*Department of Physics, University of Illinois, Urbana IL, USA*
- ¹⁶⁷*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
- ¹⁶⁸*Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*
- ¹⁶⁹*Department of Physics, University of British Columbia, Vancouver BC, Canada*
- ¹⁷⁰*Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada*
- ¹⁷¹*Department of Physics, University of Warwick, Coventry, United Kingdom*

¹⁷²Waseda University, Tokyo, Japan¹⁷³Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel¹⁷⁴Department of Physics, University of Wisconsin, Madison WI, USA¹⁷⁵Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany¹⁷⁶Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany¹⁷⁷Department of Physics, Yale University, New Haven CT, USA¹⁷⁸Yerevan Physics Institute, Yerevan, Armenia¹⁷⁹Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France^aDeceased.^bAlso at Department of Physics, King's College London, London, United Kingdom.^cAlso at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.^dAlso at Novosibirsk State University, Novosibirsk, Russia.^eAlso at TRIUMF, Vancouver BC, Canada.^fAlso at Department of Physics, California State University, Fresno CA, USA.^gAlso at Department of Physics, University of Fribourg, Fribourg, Switzerland.^hAlso at Tomsk State University, Tomsk, Russia.ⁱAlso at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.^jAlso at Università di Napoli Parthenope, Napoli, Italy.^kAlso at Institute of Particle Physics (IPP), Canada.^lAlso at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.^mAlso at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.ⁿAlso at Louisiana Tech University, Ruston LA, USA.^oAlso at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.^pAlso at Department of Physics, National Tsing Hua University, Taiwan.^qAlso at Department of Physics, The University of Texas at Austin, Austin TX, USA.^rAlso at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.^sAlso at CERN, Geneva, Switzerland.^tAlso at Georgian Technical University (GTU), Tbilisi, Georgia.^uAlso at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.^vAlso at Manhattan College, New York NY, USA.^wAlso at Institute of Physics, Academia Sinica, Taipei, Taiwan.^xAlso at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.^yAlso at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.^zAlso at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.^{aa}Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.^{bb}Also at Section de Physique, Université de Genève, Geneva, Switzerland.^{cc}Also at International School for Advanced Studies (SISSA), Trieste, Italy.^{dd}Also at Department of Physics and Astronomy, University of South Carolina, Columbia SC, USA.^{ee}Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.^{ff}Also at Faculty of Physics, M.V.Lomonosov Moscow State University, Moscow, Russia.^{gg}Also at National Research Nuclear University MEPhI, Moscow, Russia.^{hh}Also at Department of Physics, Stanford University, Stanford CA, USA.ⁱⁱAlso at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.^{jj}Also at Department of Physics, Oxford University, Oxford, United Kingdom.^{kk}Also at Department of Physics, The University of Michigan, Ann Arbor MI, USA.^{ll}Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.^{mm}Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia.